

**FEASIBILITY STUDY**  
**I-77 from I-85 to Griffith Street**

Mecklenburg County

Division 10

FS-0810B

**Task Order No. 2**

**I-77 HOV-to-HOT Lanes Conversion**

**Sub-task 2.1**

***Recommended “Best Practices” for  
HOT Lanes Operations and  
Implementation Statewide  
(Final)***

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**N.C. Department of Transportation**

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# 1.0 INTRODUCTION

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With increasing volumes of traffic using North Carolina's road network, and given the persistent physical, financial and environmental constraints to the widening of major highways, an emphasis on serving travel demand through innovative use of existing or planned roadway capacity is ever more compelling. In 2004, the North Carolina Department of Transportation (NCDOT) began to use roadway capacity more efficiently by implementing high-occupancy vehicle (HOV) lanes along 10 miles of I-77 between Huntersville and Charlotte, which represents the first and only HOV facility in North Carolina. In 2008 and 2009, the Charlotte Department of Transportation (CDOT), NCDOT, the South Carolina Department of Transportation (SCDOT) and other agencies in the Charlotte region examined existing and planned major highways throughout a 10-county region to identify where *Fast Lanes* – HOV, high-occupancy toll (HOT) or truck-only-toll (TOT) facilities – could improve roadway capacity.

In 2009, as a follow-up to the Charlotte Regional *Fast Lanes* Study, NCDOT assessed the feasibility of converting the existing I-77 HOV facility to HOT lanes, along with the possible extension of the HOT lanes north to Griffith Street at Davidson (Exit 30). The analysis performed during both the *Fast Lanes* Study and the more detailed feasibility analysis along I-77 has resulted in policy and design decisions that should be considered when HOT lanes are being studied for other corridors across North Carolina.

## 1.1 Historical Context

In highly congested corridors where traditional strategies for improving mobility and roadway capacity cannot address unmet demand, specially-designated lanes are often implemented to more aggressively manage use of these lanes so as to preserve uncongested travel speeds and improve roadway efficiency. This strategy provides a choice to motorists who otherwise would have to choose to avoid traffic congestion. In the late 1960s, managed lanes began as restricted, often curbside lanes for buses on streets and a few expressways. By the mid-1970s, carpools and vanpools, usually with three or more persons, were allowed to use some dedicated lanes, which were termed HOV lanes. In the late-1980s, changes in federal policies allowed local governments to open HOV lanes to carpools with two or more persons. By the mid-1990s, congestion pricing was tested on several HOV lanes, and the term “high-occupancy toll” lane originated. There are currently over 2900 lane-miles of HOV or HOT lanes on freeways in North America plus a wide number of lanes primarily reserved for buses on arterials. Practically all HOV or HOT lanes are located in highly congested metropolitan areas where they provide a travel time advantage over adjacent lanes.

While the term “managed lanes” is often applied to a broad range of strategies targeted at ensuring “free flow” conditions along a portion of the roadway, the term has many locally accepted acronyms and evokes different meanings and connotations depending on location or individual project. There is presently no nationally recognized definition of managed lanes. The Federal Highway Administration (FHWA) offers the following definition:

*“Managed lanes offer an enhanced operational condition within separated lanes, which result in outcomes such as greater efficiency, free-flow speeds or reduced congestion.”*

## 1.2 HOT Lanes

While many HOV projects are adequately used, some are not, leaving space for others to use the lanes. In some instances HOV demand outpaces lane capacity, potentially requiring increasing minimum occupancies of three persons per vehicle. In both cases, adding pricing to an HOV lane, creating a HOT lane, can help regulate demand better by either permitting others to use the lane or pricing some out. HOT lanes are derived from the concept of congestion pricing, which recognizes that the value of travel-time savings will vary for trips at different times and places and that these trips have different values for different individuals. These different values of time carry a real and perceived value of time-savings at the particular moment for commuters. Depending upon that self-identified value of time, commuters may elect to purchase their way into a non-congested roadway (saving time) or choose to remain in the general-purpose lanes (saving money), thus providing a commute choice.

*HOT Facility: An HOV lane or roadway in which electronic pricing is applied in conjunction with eligibility preference given to buses, vanpools and perhaps carpools to give others a travel option to use the lane. Others may include solo motorists or lower-occupancy carpools.*

The advent of electronic pricing started in the 1990s. In parallel with the growth in HOV lanes, improved technology quickly transformed the means by which tolls could be collected on toll roads worldwide. Electronic toll collection through the use of transponders located in the windshields of vehicles eliminated the need to stop and pay tolls through a conventional toll plaza.

HOT lanes offer one possible means of addressing mobility needs and helping ensure the long-term availability of HOT lanes for improved person movement. Transit buses and carpools are typically allowed to continue to use the HOT lanes for free. The toll value is set so that “free-flow” level of service for the lanes is not degraded, or the charge is maintained high enough to reflect parity with the prevailing transit fare in a corridor.

HOT lanes make the most sense when:

- The HOV facility’s adjacent general-purpose lanes are heavily congested at least during peak periods.
- Significant excess capacity exists on the HOV facility, even at its peak utilization, or significant excess capacity will be created by raising restrictions on HOV lanes that are overloaded.
- Resources are limited for either expanding roadway or transit capacity.
- The public is concerned by problems associated with utilization of the HOV lanes.

**Figure 1-1: I-94 HOT Lanes in Minneapolis**



### **1.3 Organization of the “Best Practices” Guide**

The purpose of this “Best Practices” guide is to summarize agreed-upon policies, design concepts, and other decisions reached during studies completed to date by NCDOT. The guide provides a framework for HOT lanes planning and implementation in North Carolina based on work completed during the Charlotte Region *Fast Lanes* Study, the I-77 HOV-to-HOT Lanes Conversion Study, and other HOT lane implementation projects around the country. The “Best Practices” guide covers the following:

- Chapter 2, Planning Key Steps, identifies the two-phase approach used in the Charlotte Region *Fast Lanes* Study completed in 2009. The chapter also discusses the approach typically taken in analyzing the feasibility of HOV-to-HOT lanes conversion.
- Chapter 3, Demand Forecasting, discusses the techniques used to estimate HOT lane demand both at the regional level and for a specific travel corridor in Charlotte.
- Chapter 4, Operations Policies, reviews eligibility policies, operating hours, and access policies developed during the feasibility analysis for converting the I-77 HOV facility in Charlotte-Mecklenburg to HOT lane operations.
- Chapter 5, Enforcement, highlights the latest advances in HOT lane enforcement and coordination efforts with the North Carolina Turnpike Authority (NCTA) as this NCDOT operating division implements toll roads in the state.
- Chapter 6, HOT Lanes Design, reviews design principles, typical sections, signing and marking concepts, facility access, and lane transitions. The chapter provides an overview of the toll system, business rules for calculation of tolls, toll collection and signage procedure, and communications.
- Chapter 7, Revenue Forecasting, summarizes the approach used to estimate potential HOT lanes revenue at both regional and corridor levels in Charlotte.
- Chapter 8, Implementation Parameters, outlines potential phasing for converting an existing HOV facility to HOT lanes, including construction and project delivery options.
- Chapter 9, Public Outreach, discusses public relations and outreach strategies for the introduction of, and possible changes to, HOV and HOT lanes based on national experience.

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## 2.0 PLANNING KEY STEPS

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### 2.1 Charlotte Region *Fast Lanes* Study Approach

Studies of managed lanes projects around the country indicate that successful implementation requires a thorough analysis of the technical, financial and institutional feasibility of a managed lanes strategy. All three perspectives are important, and any missing perspective can preclude successful study outcomes. The approach for the Charlotte Regional *Fast Lanes* Study involved identification of regional goals and objectives that were subsequently evaluated against the three perspectives. The study also used a two-tiered process in which study corridors were broadly screened in the first phase, followed in Phase 2 by a more detailed evaluation of those corridors which showed the most promise for managed lanes feasibility.

#### 2.1.1 Regional Goals and Objectives

The Charlotte Region *Fast Lanes* Study identified the following goals for implementing managed lanes, such as HOT lane facilities:

- Maintaining mobility
- Improving roadway operation efficiency, safety and reliability
- Promoting transit and ridesharing
- Improving safety
- Providing travel options to meet user needs, such as “time-sensitive” travel, and
- Generating revenue to offset capital and operating expenses
- Improving air quality

Regional and/or corridor objectives for HOT lanes include:

- Increasing person-moving capacity of the roadway
- Promoting transit and ridesharing mode split
- Optimizing vehicle-carrying capacity
- Promoting travel time savings, reliability, or efficiency for selected travel modes
- Promoting air quality by increasing ridesharing and transit as part of a conformity plan
- Increasing funding opportunities for new mobility improvements
- Enhancing existing transit investments and services in the region/corridor
- Providing a greater choice in serving multi-modal needs (people, goods, services)
- Improving the movement of commerce (goods and services movements)
- Supporting community land use and development goals, particularly to major areas of employment

#### 2.1.2 Phase 1 Screening Process

In the first phase of the regional study, the corridors and individual corridor segments were screened for their feasibility for managed lanes by applying criteria and thresholds that typically define effectiveness for managed lanes strategies, including HOT lanes. The



purpose of the screening criteria was to identify corridor fatal flaws before proceeding into more detailed evaluations.

The screening criteria were based on guidance from several reference sources including the American Association of State Highway and Transportation Officials (AASHTO) *Guide for High Occupancy Vehicle Facilities*, National Cooperative Highway Research Program (NCHRP) 414 *HOV Systems Manual* and *HOV Facilities Planning, Operation and Design Guide* by Parsons Brinckerhoff. HOT lane guidelines are found in the Federal Highway Administration (FHWA) *HOT Lane Guide*. The selected screening criteria responded to regional mobility goals by using the following performance measures:

- Congestion levels along a corridor or at isolated bottlenecks (required for any managed lane option)
- Travel patterns (responds to HOV, HOT or truck potential)
- Vehicle demand for HOV, HOT or truck options (responds to overall potential for effectiveness using different types of vehicle eligibility)
- Patronage demand for transit and rideshare services (responds to person-carrying potential for an HOV lane)
- Tolling potential (responds to HOT lane potential)
- Physical ability to add managed lanes, or conversely, to borrow or convert existing or programmed lanes based on current or future operations

**Table 2-1** provides a summary of the screening criteria used during Phase 1 of this study adjusted to fit more generic settings throughout North Carolina, and **Figure 2-1** illustrates the overall screening process.

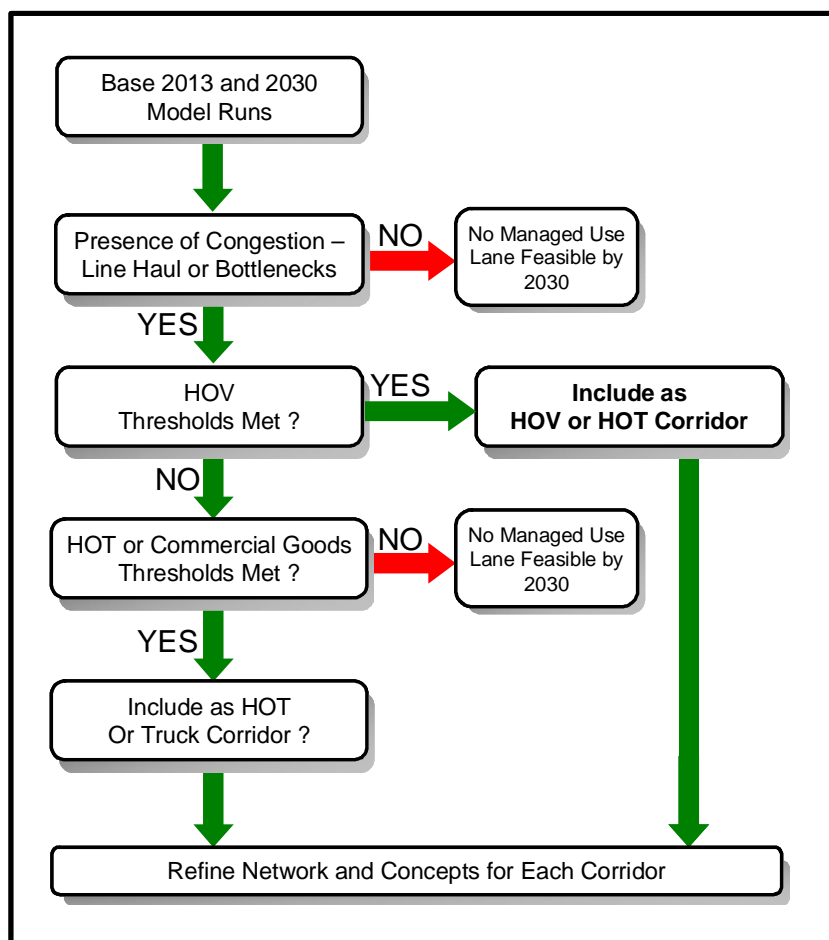
**Table 2-1: Corridor Screening Criteria**

Screening No.	Criteria	Threshold(s) to be Met	Parameters	Source
<b>Presence of Congestion</b>				
1.A	Line- haul	Freeways: Volume/capacity (V/C) greater than 1.0 and average speeds below 30 mph in the peak period.  Arterials: V/C greater than 1.0 and average speeds below 20 mph in the peak period.	Travel speeds  Volume/capacity ratio	Regional travel demand forecasts based on existing and proposed roadways for a near-term and design year (typically 20 years or more from the existing year)
1.B	Bottlenecks (less than 0.5 miles)	V/C below 1.0  Speeds below 20 mph	Travel speeds  Volume/capacity ratio	Regional forecast output .
<b>HOV Demand</b>				
2.A	Travel Patterns	Freeway corridors: Average trip distances of 5 miles or more.  Arterial corridors: Average trip distances of 3 miles or more.	Vehicle volumes  Threshold is either met or not met for each defined corridor or combination of corridors for a defined commute-shed.	Regional model select link forecast demand.  Not applied to connecting route segments in core of region.
2.B	Person Moving Demand	Parity or greater when compared to general purpose lane person movement in same corridor, on a per-lane basis, assuming 2000 persons/general purpose lane.	Person moving demand basis for vehicles must be capped based on a maximum per-lane flow rate of 1650 passenger car equivalents (PCEs) per hour for freeways and 900 PCEs per hour on arterials.  Threshold is either met or not met.	Carpool forecasts from regional model (design year only)  Recent vehicle occupancy surveys  Transit patronage estimates where number of carpools is below thresholds.
2.C	Vehicle Demand	HOV Freeway: 600 PCEs/hour minimum  HOV Arterial: 200 PCEs/hour minimum	Vehicle demand determined for peak period. Maximum volume is 1650 PCEs/lane  Criteria is met or not met.	HOV demand for near-term and long-term forecasts. Confirm through national sketch planning techniques for select corridors.

**Table 2-2 (Continued): Phase 1 Corridor Screening Criteria**

Screening No.	Criteria	Threshold(s) to be Met	Parameters	Source
<b>HOT or TOT Demand</b>				
3.A	Travel Patterns	Freeway corridors: Average trip distances of 5 miles or more for commuters or large trucks.  Arterial corridors: Average trip distances of 3 miles or more.	Vehicle volumes  Threshold is either met or not met for each defined corridor  Not applied to connecting route segments in core of region.	Regional model link data for design year forecast
3.B	Vehicle Demand (2013 and 2030)	HOT Freeway: 1000 PCEs/hour minimum HOT Arterial: 400 PCEs/hour minimum Commercial movement demand 400 large trucks directionally/hour x two lanes= 800 trucks/hour Common origins/destinations > 5 miles using corridor	Vehicle demand must be capped based at a maximum per-lane flow rate of 1650 PCEs per hour for freeways and 900 passenger car equivalents per hour on arterials.  Criteria is met or not met for each vehicle group	Demand from regional model for near-term and long-term forecasts
3.C	Revenue Potential	Forecast revenue (gross) for screening stage	Rapid toll optimization model results based on regional travel forecasts per corridor	Regional model forecasts that simulate toll conditions or applied to a sketch planning toll optimization model for selected forecast years
<b>Physical Attributes</b>				
4.A	Physical Feasibility-Add a lane	Space to add a managed lane (typically a minimum of 16 ft per direction)	ROW and roadway characteristics for each corridor	Aerials  As-built plans  Project plans implemented by design year
4.B	Physical Feasibility-Convert a lane	Ability to convert or borrow an existing lane or shoulder for a peak hour or direction (reversible lanes), without more than one degradation in LOS for traffic in the remaining lanes; no spillover traffic onto other routes.	Resulting volumes cannot exceed 2000 vph for conversion, or reductions in lane, shoulder widths acceptable.	ADT/lane in peak hours for near-term and long term  Current observed LOS on existing corridors to validate existing conditions

**Figure 2-1: Screening Process**



### 2.1.3 Phase 2 Detailed Analysis

During this phase of the regional study, costs, tolls and revenues were analyzed, as well as other factors affecting implementation of managed lanes in the Charlotte region. Phase 2 involved estimating capital, operating and maintenance costs for each corridor advancing beyond Phase 1 screening to determine the initial financial feasibility of a managed lanes strategy. As appropriate for a first-order assessment of a HOV or HOT lanes network at a regional scale, simplified, yet conservative approaches to estimating revenues and costs were used. Capital and operating and maintenance costs included significant contingencies.

The following factors were used to evaluate corridors in Phase 2 of the Charlotte Region *Fast Lanes* Study:

- **Demand.** The projected number of persons and vehicles using a HOV or HOT lane during peak periods, particularly when compared to forecasted trips in the adjacent general purpose lanes.
- **Travel time savings.** The estimated time saved during peak periods by managed lanes users compared to motorists traveling in the general-purpose lanes. The number of

minutes saved per mile on the managed lane facility was used to evaluate each corridor and corridor segment.

- **Comparison of estimated revenues to forecasted capital and O&M costs.** The extent to which projected revenues for a corridor or corridor segment cover estimated capital and O&M expenses. This revenue-to-cost comparison over a life cycle period provides a general indication of the financial feasibility of implementing HOT lanes in a corridor.
- **Other projects or studies impacting the timing of HOV or HOT lanes implementation.** Impacts on managed lanes implementation from corridor improvements which have been completed or are already funded and programmed.

#### **2.1.4 Conclusions for the I-77 North Corridor from the *Fast Lanes* Study**

The travel demand for managed lanes in the I-77 North corridor ranked near the top of corridors assessed in Phase 2 of the regional study. The forecasted travel time savings for managed lanes users in 2030 would exceed the industry rule-of-thumb of a half-minute per mile savings. These results were based on development of a regional managed lanes network. The *Fast Lanes* study concluded that I-77 North should be analyzed at the individual corridor level for implementation, including possible HOV-to-HOT conversion and extension of a priced facility.

## **2.2 I-77 HOV-to-HOT Lanes Conversion Feasibility Study**

### **2.2.1 I-77 HOT Facility Objectives**

The objectives established in 2003 during the initial implementation of I-77 HOV lanes included:

- Move more people by increasing the number of persons per vehicle.
- Reduce travel time and ensure reliable trip times for HOVs using the I-77 managed lanes.
- Operate a safe HOV facility and not unduly impact the safety of the I-77 general purpose lanes.
- Maintain or improve public support for the I-77 HOV facility.

Based on the evaluation of the existing HOV lane against the objectives established in 2003 and the experience of other HOT lanes around the country, the following objectives for the proposed HOT lanes along I-77 include:

- Increase mobility in the I-77 corridor by moving more persons per vehicle and more vehicles than the number presently being carried in the HOV lanes while not impairing person movement.
- Reduce travel time and ensure reliable trip times for all eligible users for a HOT lane conversion of the I-77 HOV lanes.
- Operate a safe HOT lane facility and preserve the safety of the I-77 general purpose lanes.
- Test acceptance and maintain or improve public support for the I-77 HOT facility.

- Improve enforcement compliance.
- Demonstrate variable pricing as a means of improved lane management.

### 2.2.2 Key Planning and Policy Criteria for HOV-to-HOT Lane Conversion

HOV lanes, like the I-77 HOV facility, which experience chronic underutilization (below 700 vehicles per lane per peak hour) comprise a pool of potential candidates' for conversion to a HOT lane<sup>1</sup>. In these cases, the presence of an optimal toll set to maintain a minimum operating standard on the HOT lane could divert low-occupancy vehicles onto the HOT lane.

Underused HOV lanes are considered the best candidates for conversion because:

- no additional lane capacity needs to be added to the existing operating envelope, and
- the minimum vehicle occupancy requirement does not have to be adjusted.

HOV lanes that experience chronic peak hour congestion also reflect a mismatch between existing travel demand and lane capacity, and merit some type of change in operation to address delays.

Based on considerations such as those described above, the planning process should address a number of questions to determine how effectively a potential HOT conversion project addresses a current unmet transportation need. These include <sup>1</sup>:

- Is there sufficient excess peak capacity to allow single occupancy vehicle toll buy-ins on an existing HOV lane without the need to expand lane capacity? The feasibility of a potential conversion project depends in large part to the amount of excess capacity that can be sold to solo drivers. If there is abundant excess capacity on the existing HOV lane and traffic congestion on highway mainlines is moderate, it may be feasible to attract just enough single occupant vehicles onto the HOT lane through optimally priced dynamic tolling without necessitating any change in HOV use. The level of excess capacity may need to be enough for tolling to at least pay for the added O&M cost involved.
- If there isn't enough excess peak capacity in the existing HOV lane(s) to allow for tolling of solo drivers, is there additional capacity that can be added to the existing HOV facility through restriping or modest widening as part of an HOT conversion project? Many HOV lanes are single-lane facilities with limited separation from adjacent general purpose lanes. In cases where the potential market for premium HOT-lane service is large and mainlanes suffer from severe to extreme peak congestion, it may be necessary to:
  - 1) change the HOV exemption from HOV 2+ to HOV3+ or higher,
  - 2) add a second HOT lane,
  - 3) require HOVs to carry transponders even if they are given free use,
  - 4) toll lower occupancy HOV2s,
  - 5) perform more aggressive enforcement to remove violators (thereby freeing up some capacity for others)
  - 6) consider a combination of the above strategies.

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<sup>1</sup> Consideration for High Occupancy Vehicle (HOV) Lane to High Occupancy Toll (HOT) Lane Conversions Guidebook. U.S. Department of Transportation, Federal Highway Administration, June 2007.

- If changing the HOV exemption from HOV-2+ to HOV-3+ or higher is necessary in conjunction with pricing, will it result in modal, spatial, or behavioral shifts that undermine the mobility improvement objective? The existing HOV eligibility status in the HOV exemption policy should be preserved in the HOT lane context whenever possible. In many instances, however, preserving the current HOV exemption may not free up enough capacity to sell to lower occupancy vehicles which are willing to pay a toll for premium HOT lane service. If the exemption is increased from HOV-2+ to HOV-3+, the magnitude of HOV-2s that disband or shifted back into the mainlanes may offset any increases in carpooling motivated by the presence of tolling. Should the ultimate effect be a net reduction in HOVs and a net increase in lower occupancy vehicles, this may undermine one of the key objectives underlying the HOT lane concept, which is to promote person and vehicle movement.
- Are there any unique operational and physical characteristics of the existing HOV lane facility that will require major reconfiguration? Not every HOV facility, under its current operating configuration, can be readily converted to HOT use without some significant physical improvements to the existing roadway. In addition to improvements which limit ingress and egress to the HOT facility, it may be necessary to modify lane configurations both at the entry and exit points of the HOT facility to minimize queuing at bottleneck locations. The HOT lanes will also have to accommodate additional median mounted signing and traffic control devices, such as advance signs to access points, variable toll message signs (VTMS) and electronic toll collection equipment and supporting gantries and cabinets, and maintenance areas and enforcement monitoring areas.

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## 3.0 DEMAND FORECASTING

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One of the key components in assessing the viability of managed (HOV or HOT) lanes centers on projected facility use. This chapter summarizes the demand forecasting approaches used in the Charlotte Regional *Fast Lanes* Study and the I-77 HOV-to-HOT Lanes Conversion Feasibility Study. Other study settings would rely on similar regional models available.

### 3.1 Regional Travel Demand Model

Charlotte and the surrounding counties rely on a state-of-the-art, computerized travel demand tool, the Metrolina regional travel demand model, for various transportation planning activities. The regional model was originally developed in 1980 based on the traditional four-step planning process. Over the years, this model has been refined to include the latest developments and uses a TransCAD software platform. Because the original intent of the model was not to analyze managed lanes, many enhancements and post processing routines were required during the Charlotte Region *Fast Lanes* Study and the I-77 HOV-to-HOT Lanes Conversion Feasibility Study. As additional refinements are made to this and similar regional models, the ability to apply the model to managed lanes and toll applications will undoubtedly improve. The remaining sections of this chapter describe how the Metrolina regional model was used during both studies.

#### 3.1.1 Presence of Congestion

To ensure successful implementation of HOV or HOT lanes, existence of congestion along a corridor is the most critical factor to justify managed lanes. The Metrolina model includes an extensive highway network, including all interstates in the region. The interstates were coded as one-way links by direction, which facilitated summarizing data for the Charlotte Region *Fast Lanes* Study. In order to identify congestion, links were evaluated using congested travel speeds and volume-to-capacity ratios. This approach allowed for analyzing congestion related to line-haul traffic movement. Because the regional model was not set up to reflect delays as a result of critical intersection/interchange locations, capacities on the network links approaching these points were adjusted to account for congestion. Most bottleneck locations were identified based on local experience of the staff of the Charlotte Department of Transportation and field observations. Managed lanes are generally not warranted unless the following congestion thresholds (as proxies for success) are met:

- Speeds below 35 miles per hour (mph) on freeways and 20 mph on primary arterials and/or volume-to-capacity ratio above 1.0.
- Congested durations of at least two hours, and preferably three hours for each peak period by the design year.
- Congested segments are frequently identified as either “line-haul,” defined as successive corridor segments experiencing congestion that often is reflected in extensive queueing, or bottlenecks where queueing is isolated. While the definition of a bottleneck is somewhat subjective, its intent is to address an isolated location that may be remedied by transportation system management (TSM) treatments other than added lane capacity along the corridor. (HOV and HOT lanes may effectively address a



bottleneck, but such an application would be in context with a TSM/TDM action and not necessarily justified as a corridor or regional solution.)

### **3.1.2 Vehicle and Person Demand**

HOV demand focuses primarily on person movement, while HOT operation prioritizes person movement while also moving as many vehicles as possible. Thresholds for vehicle movement are only intended to assure a minimum level of perceived use, since a rather small number of bus vehicles can move a significant volume of persons often equal or greater than what a general purpose lane can carry. Person movement represents the highest and best use of managed lane efficiency while a minimum level of vehicle visibility is needed to show that the lane can be adequately accepted by stakeholders by HOVs alone. Therefore, obtaining or synthesizing peak hour forecasts is critical since demand and justification for managed lanes may only exist for selected hours. For example, the Metrolina model is a time-of-day model. Because the model uses three-hour morning and afternoon peak periods, a six-hour mid-day off-peak period, and a 10-hour evening/night off-peak period, it was able to report vehicles and persons during each of the four daily periods. Hourly vehicle and person demand was an off-model calculation based on Metrolina model data exported to a spreadsheet. A similar process may be expected using any regional model.

#### ***Person Moving Demand***

Existing and likely levels of person movement—primarily transit, carpool and vanpool demand—are an early study indicator of managed lane effectiveness. Vehicle occupancy counts coupled with traffic forecasts for each user group are typically generated for this determination. Minimum existing demand is critical to determine whether a managed lane can be considered a success in its opening year. For example, an HOV lane should move more people than a general purpose lane would by the forecast year, although in early years it still needs to meet a minimum level of use.

The level of bus transit service represents the highest potential to improve person movement in a corridor, and thus, the highest level of effectiveness that may be achieved for a managed lane. Bus volumes, existing or forecast, often justify consideration of some type of managed lane treatment, particularly through traffic bottlenecks. Input values can include the number of buses in the peak hour or period along with anticipated patronage levels.

#### ***Vehicle Demand***

A minimum threshold for vehicle demand needs to be present for any managed lane strategy to gain public support even in the early years of operation, and this value varies between freeway and arterial treatments. At the other end, for the purpose of the Metrolina model analysis, freeway and arterial managed lanes operational threshold capacity was capped at 1,650 and 900 passenger car equivalents (PCE) per hour per lane respectively, otherwise the lane would not be able to assure travel benefits. (Future editions of the Highway Capacity Manual may be referenced with more specific guidance.)

### **3.1.3 Travel Patterns**

Another key success factor in assessing the feasibility of managed lanes relates to regional travel patterns. Managed lanes are more attractive to motorists taking longer trips because mode or spatial shifting requires a minimum level of time savings to generate demand. Based on national experience of existing managed lanes, commuters in a common travel shed gaining a travel time savings of at least three minutes, and preferably five to eight

minutes, are a good indicator for using managed lanes. The comparable distance for commercial vehicle trips may be longer. Analysis of travel patterns (select link analysis in travel demand forecasting) helps in identifying potential origin and destinations and access locations along proposed HOV lanes.

Specific traffic bottlenecks or congestion points may cause significant delays, and they are often found at interchange merges, bridges and signals. The existence of bottlenecks may point to the need for isolated dedicated lane or signal/metering treatments such as direct access ramps, managed lane shoulder use or connector metering with other queue bypass strategies.

## **3.2 Model Limitations and Adjustments**

During the Charlotte Region *Fast Lanes* Study, the following model adjustments were made to forecast HOV lane demand. The following summarize the adjustments to the Metrolina travel demand model in order to perform managed lanes analysis.

### **3.2.1 Network and Links**

The managed lanes network was coded on top of the existing Metrolina region highway system. The new links representing managed lanes were coded with link attributes to reflect proposed operations. Based on experiences from similar studies, capacities of HOV lanes had to be lower than regular general purpose lanes in order to limit vehicle diversion and restrain capacity to maintain a higher level of service on the managed lanes. During the *Fast Lanes* study, existing general purpose lane capacities and speeds were analyzed and Highway Capacity Software (HCS) was used to determine the capacity of managed lanes. These links were coded as two-way links with a capacity of 1,650 vehicles per hour per lane. The network links along the proposed study corridors were further refined to meet the objectives of the Charlotte Region *Fast Lanes* Study and the I-77 HOV-to-HOT Lanes Conversion Feasibility Study as follows:

- The original interstate links were modified so that the break points (nodes) of the managed lane link and general purpose links would fall in the same vicinity. Splitting of the original links facilitated in adding access links and also ensured consistency in comparing results with and without the managed lanes.
- One of the feasibility criteria for managed lanes was the physical condition of the existing interstate segments. Because there were freeway sections with no additional right-of-way, minimum-width medians and/or shoulders, or wide medians, the original links were modified to reflect changes in physical and operational attributes as well as logical termini, including political boundaries, to summarize model data output.

### **3.2.2 Access**

Identification of access locations for the managed lanes was an iterative process. The initial model runs provided for unrestricted access between the general purpose and managed lanes. After analysis of the first model run, selected access links were eliminated because of low demand and access links also were eliminated or moved to maintain the preferred access frequency of every two to three miles. The model was also used to test direct access ramps by connecting HOV lanes to surface streets. This strategy provides additional

benefits to vehicles using managed lanes because it reduced weaving from managed lanes to exit ramps and provided travel time savings from congestion at off and on ramps.

### **3.2.3 HOV Trip Table**

The Metrolina regional model has trips grouped into various categories of vehicle types, such as single occupant vehicles, carpools with two persons, carpools with three or more persons, commercial vehicles, medium and heavy trucks. Because the model cannot increase the number of HOVs because of improved benefits, the number of HOV vehicles allowed in the managed lanes was based on only the limited universe of carpools with two persons and three or more persons (no new carpools were formed).

### **3.2.4 Model Calibration**

Additional traffic counts were conducted for the existing HOV lanes north of LaSalle Street overpass. Traffic counts conducted at key locations along the study corridor were used to test the calibration of the regional model.

### **3.2.5 Travel Time Savings**

In order to evaluate changes in travel times, sample origins and destinations were identified which would represent the primary movements most likely to use the *Fast Lanes* studied in Phase 2. Existing travel times were evaluated as part of the calibration process. Also, travel times were compared between future no-build and build options to gauge the benefit of the options being considered.

### **3.2.6 HOT Lane Trips**

Because the existing Metrolina travel demand model was not capable of estimating HOT lane volumes, volume estimates for HOT facility scenarios were based on HOV assignments. A separate tolling model which took HOV lane inputs and estimated HOT lane volumes based on diversion observations at similar facilities around the country was used during the Charlotte Region *Fast Lanes* Study.

### **3.2.7 Operational Analysis**

Because the Metrolina model is a regional model, it is not detailed enough or calibrated adequately to be used in operational analysis a corridor or sub-corridor level. Volume outputs from the Metrolina and tolling models were used as input to a freeway simulation model such as CORSIM. CORSIM is a traffic simulation model that is appropriate for micro-level corridor operational analysis. There are other simulation tools which may be applicable based on the unique traffic conditions prevalent. Operational analysis of various improvement alternatives provided valuable insights that were used as feedback to the Metrolina regional model.

## **3.3 Model Scenarios**

The latest calibration of the Metrolina model was based on 2009 conditions. For the purpose of Charlotte's regional study, model runs were developed for 2013 and 2030. Volume forecasts for years between 2013 and 2030 were based on straight-line

interpolation. Three HOT lane options (see **Figure 3-1**) were evaluated for both 2013 and 2030.

### **3.3.1 Option 1**

Option 1 assumed that the existing HOV lanes would be converted to HOT lanes with no additional general purpose lane capacity.

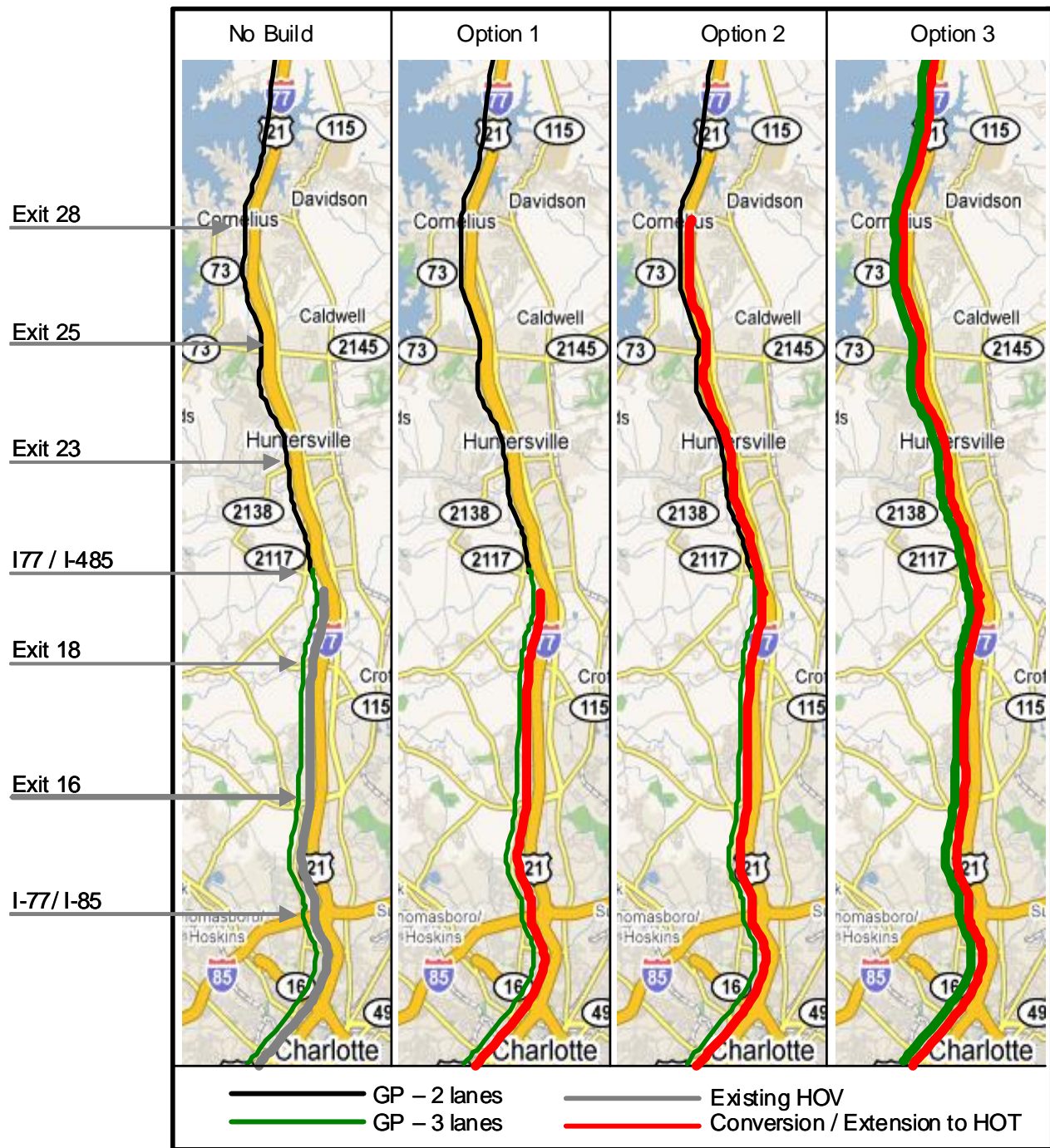
### **3.3.2 Option 2**

Option 2 assumed that the existing HOV lanes would be converted to HOT lanes. In addition, it was assumed that one new HOT lane, in each direction would be added from the end of the current HOV facility, just north of I-485 (Exit 19), to Catawba Avenue (Exit 28).

### **3.3.3 Option 3**

Option 3 assumed that the existing HOV lanes would be converted to HOT lanes. In addition, it also assumed that two new lanes would be added in each direction from the terminus of the existing HOV facility to Griffith Street (Exit 30). One new lane would be an extension of the HOT lanes while the second lane would be an additional general purpose lane.

**Figure 3-1: HOT Options**



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## 4.0 OPERATIONS POLICIES

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This chapter reviews recommended eligibility policies, operating hours, and access policies, approved for the I-77 HOT lanes in Mecklenburg County during the analysis of their possible conversion from a HOV to HOT facility. The recommendations are a continuation of policies implemented in 2004 when the I-77 HOV lanes were opened between Charlotte and Huntersville.

### 4.1 User Requirements

In general a HOT lane should not adversely affect the HOV traffic stream nor the adjacent general traffic. For this reason, conversion is typically only considered for HOV lane treatments; general traffic lanes have never been converted for pricing purposes as of 2010. Future projects in North Carolina may open new lanes as HOT lanes. For the I-77 conversion study, HOT lanes would continue to be open and free to vanpools and carpool vehicles carrying two or more occupants. The following sections summarize changes in facility use for various groups following possible HOV-to-HOT conversion:

- **Motorcycles.** While federal law requires HOV lanes to be open to motorcycles regardless of the number of riders, there is no rationale not to allow motorcycles to use the HOT lane so long as they carry a transponder and pay the requisite fee. They would lose free status to ride in the lane once it is converted but would be eligible along with all other general traffic.
- **Emergency Vehicles.** The term “emergency vehicle” means any law enforcement, fire, police, or other government vehicle, and any public or privately owned ambulance or emergency service vehicle, when responding to an emergency. Emergency vehicles would be exempt in all cases from paying a toll; however, such vehicles need to be easily distinguished and be responding to an emergency to be eligible for free use.
- **Buses.** Any public or private transport vehicle designed to transport 15 or more passengers, regardless of the actual number of occupants, would be free to use the HOT lane regardless of whether they are carrying the requisite number of passengers or not (typically in a deadhead mode).
- **Trucks.** Any motor vehicle with three or more axles would be precluded from using the HOT lanes, continuing the current prohibition for use of the I-77 HOV lanes for safety reasons. Commercial vehicles with two axles, such as delivery trucks, could use the HOT lane as long as they carry a transponder and pay the requisite toll.

### 4.2 Operating Hours

Typically operating hours for HOT operation should address periods of time where demand exists, but may not necessarily operate all day or on a 24-hour basis. For example, the existing I-77 HOV lanes operate 24 hours a day, seven days a week. The rationale for this decision was based on the design of the facility which departs from the freeway main lanes onto a separate roadway alignment through the I-85 interchange. Opening up this lane and roadway for certain time periods could cause potential confusion for motorists and could represent a safety hazard, particularly at night.

For this reason, it was determined that the existing operating hours for the I-77 HOV lanes would not change under a HOT lanes conversion. The extended HOT facility would operate

24 hours a day, seven days a week. The hours of operation may be relaxed to a low toll rate during off-peak periods, and it may not be monitored or enforced during these periods. The hours of operation for user-only restrictions may be waived at any time for a portion or the entire facility if, in the opinion of the staff of NCDOT's Metrolina Region Traffic Management Center (MRTMC), the HOT lane should be opened toll-free to all traffic to bypass general purpose lane or roadway closures due to major incidents or road construction/maintenance activities. Hours of operation would be posted at entrances to the HOT lanes.

### **4.3 Access Policy**

Safety experience shows that managed lanes can operate equally well whether access is open or restricted. However, for pricing applications on HOT lanes, access generally has to be restricted. Tolling systems are placed within each operable “zone” between access openings. Without restricting access, more investment in frequent toll readers and other infrastructure may be required, at least for existing technologies and applications. The access policy also takes into account the bottleneck locations and roadway geometry. For example during the I-77 feasibility study, it was decided that the current HOV facility access policy would remain in effect for the conversion of the existing HOV lanes to HOT lanes and any facility extensions. Access to the HOT lanes would be permitted at designated locations. Access would be restricted in order to properly toll specific segments of the project. Access also would be restricted where there are operational or safety issues associated with merging traffic. Access restriction would typically be represented by a two wide solid stripes defining a non-traversable buffer. Areas permitting ingress and/or egress to the HOT facility would be designated by appropriate signing and a wide single white skip line located between the HOT lane and the leftmost general purpose lane. Signing would appear at periodic intervals indicating that the buffer cannot be crossed.

Direct access ramps could be included as part of the initial HOV-to-HOT conversion phase or added in a subsequent I-77 project development phases. Direct access ramps could provide high-speed access to I-77 from another route, such as I-85 or I-485, or to connect to adjacent streets and transit facilities. Possible direct connections to the I-77 HOT lanes involved the following locations:

- Bailey Road Extension
- Stumptown Road
- Mt. Holly-Huntersville Road
- Lakeview Road

Unless otherwise restricted, direct access ramps would be designed and operated to serve all types of HOT lane traffic.

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## 5.0 ENFORCEMENT

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Enforcement is critical to the successful operation of any HOT lane facility. An effective enforcement program should help ensure that operating requirements, including occupancy and access enforcement are maintained to preserve travel time savings, discourage unauthorized vehicles, and maintain a safe operating environment.

This chapter reviews HOT lane operational unique issues and challenges associated with enforcement. Enforcement strategies used in several HOT lanes similar in scale and length to the projects reviewed in this study are discussed.

### 5.1 Typical HOT Lanes Operations

HOT lanes are toll facilities that charge a toll to all HOT lane users except for vehicles that meet the minimum occupancy for toll-exemption eligibility. In order to deter violations and reserve capacity for users, the HOT lane operator must be able to identify violators who use the HOT lane without paying. In addition, the HOT lane operator must be able to distinguish between vehicles required to pay the toll and HOVs that are eligible for toll-exemption.

Most HOT lanes today that use electronic toll collection (ETC) require users to establish a prepaid account from which toll transactions are debited for HOT trips taken. The requirement for users to have an active HOT lane account provides a partial solution for toll lane enforcement. Because all vehicles are required to have an active HOT lane account, motorists entering the HOT lane without a valid account are, by definition, considered in violation of the usage policy. Image capture technology is very reliable and can be used to read and capture license plate information (sometimes referred to as “pay by plate”) to augment ETC tolling systems. With this information, HOT lane operators can issue violation citations, collect tolls which are owed, and process fees as is done for other North Carolina toll facilities.

### 5.2 Facility Design Considerations

Facility design is also an important element of HOT lane enforcement. Barrier-separation features can be effective in deterring potential violators, but barrier separated systems also require additional space along the facility to monitor, apprehend, and cite violators. Barrier-separated facilities generally make apprehension fairly easy because the violator is confined within the lanes after entry. It is notable that the larger the facility (i.e., number of lanes) and the larger the quantity of entry and exit points, the more difficult manual enforcement becomes.

Non-barrier separated HOT lanes are more difficult to enforce because it is easy to enter and exit the lane simply by changing lanes. Plastic lane delineators such as those used on the 91 Express Lanes in California can deter violators. Locations where delineators are used typically do not have adequate shoulder space for effective road side enforcement.

Police need to determine who is a free user versus those who have paid. The best place to perform this function is in the vicinity of the tolling gantry where a monitoring area is provided for stationary enforcement. In-vehicle or roadside devices tied to the tolling system can alert police to the transaction status of each passing vehicle so that they know who has paid.



Actions to enhance the performance for HOT violation enforcement include:

- During the design phase, have engineers meet with state highway patrol officials to determine locations best suited (safe, adequate space) for road side enforcement.
- If there is adequate space, consider installing concrete barriers or delineators.
- Prominently post the fine for HOT violations on roadside signs.
- Use random visual, saturated enforcement followed by routine enforcement as a strategy to manage violators.
- Contract with dedicated police to manage enforcement.

### **5.3 HOT Lane Enforcement Functions**

Enforcement is critical if a HOT lane facility is to be successful and effective. The enforcement strategy and the technology implemented must be reliable, highly visible, and one that promotes fairness. Although using enforcement vehicles to stop apparent violators may not be the most efficient method to catching occupancy violators, it is the most visible to the public, including the public traveling in the general purpose lanes. This visible enforcement effort demonstrates that the agency or entity controlling the use of the managed lanes is serious about maintaining the integrity of use by vehicles qualified to be in the designated managed lanes. Enforcement of HOT lane usage must accomplish the following key operational functions:

- Verify toll payment (or credit)
- Verify vehicle occupancy
- Assess a fine to violators.

#### **5.3.1 Verify Toll Payment**

Most current AVI systems rely on RFID technology, which enables communication with a transponder affixed to a vehicle via Dedicated Short Range Communications. A transponder is an RFID device that, when mounted on a vehicle's windshield, enables the HOT lane operator to collect an electronic toll as it passes underneath the toll zone.

The 'reading' of the transponder may occur while the vehicle is traveling at stop and go or highway speeds. The AVI system typically consists of an antenna and reader installed above a toll lane to automatically "read" or identify the transponder, and the vehicle associated with it.

#### **5.3.2 Verify Vehicle Occupancy**

Accurately determining the number of vehicle occupants poses a tremendous challenge. When volumes rise, it is difficult to catch all violators, let alone distinguish violators from eligible HOVs. From time to time, an enforcement officer mistakenly stops HOVs because an occupant in addition to the driver (e.g. small child) is not readily visible in the back seat. Enforcement of occupancy requirements is perhaps the most difficult operational challenge facing toll agencies because automated technologies have not yet met reliability and field accuracy requirements needed for operational deployment. In addition, there are a host of cost and privacy considerations associated with the use of such detection technology.

The technical support used to supplement manual enforcement typically consists of a gantry mounted violation indicator light to provide an indication for near-by enforcement vehicles to respond to. Additionally, some facilities use video cameras together with an OCR system to capture the license plate image of the vehicle as it passes through the toll zone. The camera may be mounted above the roadway or along side the roadway, depending on the design of the HOT facility and the violation objectives of the facility. Once the license plate image is captured, it must be correctly 'read' by the OCR in order to successfully locate the vehicle owner to collect the toll and if applicable, the toll evasion fine.

### **5.3.3 Assess Fines to Violators**

Violations fall within two classes: a) enforceable (no transponder read, but license plate read; vehicle not linked to an active account), and b) unenforceable (no transponder read and no license plate read). An effective HOT enforcement program should attempt to keep violations (enforceable and unenforceable) to at or below 10 percent of total trips.

HOT lanes typically require the creation of local ordinances that carefully document the process for resolving violations. The ordinance should establish a multi-stage notification process, which is a graduated fine structure typically used to assess different penalties for first-time violators versus habitual offenders.

In California, for example, the 91 Express Lanes uses the following graduated violation structure:

- Notice of Toll Evasion (NTEV) – \$20
- Notice of Delinquent Toll Evasion (NDTEV) – \$55
- Notice of Toll Violation Assignment – \$80

The Orange County Transportation Authority (OCTA) reports that of the total number of enforceable violations, 60 percent are dismissed with no penalty, 11 percent pay toll and the penalty and 20 percent go to collections. Over 80 percent of all enforceable violations are addressed at the NTEV/NDTEV stage.

## **5.4 Enforcement Assumptions for I-77 HOT Lanes**

During the analysis of converting the existing I-77 HOV facility to HOT lanes, enforcement assumptions were made to estimate HOT lane facility operations and maintenance costs. These assumptions reflected input from NCDOT/NCTA as this agency develops enforcement procedures for Triangle Parkway, the first modern toll road in North Carolina, which will open to traffic in 2011.

Enforcement of the I-77 HOT lanes is critical to the operational performance of this facility and perceived system reliability by prospective users, particularly the single-occupant vehicle users who are required to pay for time savings and travel performance relative to the general purpose lanes. HOT lane design elements can contribute to violations and add complexity to finding a solution that does not unduly affect operational performance resulting from either a lack of or too much enforcement. Signing must be clear and properly located for users to quickly assess the costs and benefits of using the HOT lanes and to avoid misunderstanding the rules governing the use of the facility.

The types of violations that could occur along I-77 HOT lanes include:

- **Occupancy.** Vehicle contains fewer occupants than what is required for HOV status. This determination would be assessed by on-site visual NCSHP enforcement personnel who would focus on users having a disabled/inoperative transponder or a current HOV registration (assuming all are registered users) and vehicles without a valid transponder when the system is capable of only identifying and handling single-occupant vehicle users. In this case, all violations except vehicle type are occupancy violations.
- **Vehicle Type.** Vehicle does not meet the following classification types that are allowed for HOT travel:
  - Passenger vehicles (including light trucks and vans)
  - Buses (public and privately owned) and qualified courtesy vehicle with no axle count limitation
  - Motorcycles
  - Emergency vehicles.

The two primary methods of enforcing the above violations can be categorized as automated and manual. For occupancy violations, the I-77 HOT Lanes Enforcement Plan will describe and evaluate alternative automated methods for detecting and enforcing occupancy violations. However, there is no field-proven, cost-effective automated means to accurately determine occupancy violations within vehicles. For all operating HOT lane facilities within the United States, vehicle type violations rely exclusively on manual on-site enforcement, so no alternative analysis is warranted. Although the last violation type listed applies only when the system is capable of identifying all authorized users, the advantages and disadvantages of manual and automated enforcement for this violation type merits analysis. Time-tested, field-proven, automated enforcement method for unauthorized facility users (i.e., violators) involves image capture of license plate numbers by overhead mounted cameras. Image files and associated transaction records are transmitted to a violation processing site where optical character recognition is used in conjunction with manual review, confirmation and plate number extraction (when needed). Pursuant to the terms of an agreement, license plate numbers could be sent to the NCSHP to obtain registered vehicle ownership information, which is used to mail a citation to the registered owner. For the purposes of the comparison below, automated enforcement is defined as license plate recognition (LPR) in which an image capture is forwarded for review.

The advantages and disadvantages of manual and automated enforcement include:

#### **Manual Enforcement Advantages**

- Presence of NCSHP at observation and enforcement areas along the I-77 HOT lanes will demonstrate to prospective single-occupant vehicle users NCDOT's strong commitment to minimizing violations and the associated degradation to operating performance.
- If the system is capable of distinguishing HOV and single-occupant vehicle users, historical violation tracking allows enforcement details to be scheduled for days and times when the incidence of violations is highest.
- Enforcement operations for the HOT lanes also eventually benefit from other projects in the region, particularly for occupancy violations.

- Presence of the NCSHP along the HOT lanes when a traffic incident occurs will minimize response time and the length of time the facility is either closed or not meeting performance objectives.
- Manual enforcement is the only means of getting the attention of habitual violators who disregard mailed citations and may drive without current vehicle registration, thereby eliminating another means of recovering all or a portion of the amount owed.

### **Manual Enforcement Disadvantages**

- The mere presence of NCSHP at observation and enforcement areas can adversely affect traffic flow on all lanes.
- NCSHP presence will not likely be continuous based on the level of budget dedicated to enforcement, and if enforcement periods are not random, the probability of commuters violating during days and times when the HOT lanes are known to be without enforcement could be higher.
- When a transaction status indicator light indicates a potential violation, the anticipated NCSHP procedure of entering the traffic stream to pursue the targeted user, positioning the patrol car or motorcycle behind the suspected violator, pulling over the user on the left or right shoulder, and if on the left shoulder, either confirming and issuing a citation there or instructing a confirmed violator to pull over at a recognizable downstream enforcement area will adversely affect traffic operations and cause disruption in free-flow conditions.
- Cost increases resulting from expanded NCSHP patrol service and escalation in labor and equipment costs can be expected over the life of the I-77 facility if not supplemented by automated enforcement.
- Conducting enforcement assignments with NCSHP officers operating in tandem to reduce the impact on traffic operations will increase enforcement costs and may not represent the highest use of a limited, publicly funded resource, particularly if the number of citations issued per suspected violator pursued is low.

### **Automated Enforcement Advantages**

- Provides continuous enforcement of unauthorized users during facility operating hours.
- Expected to significantly reduce the adverse impact to traffic operations caused by enforcement operations by at least limiting pursuit to occupancy and the expected occasional vehicle type violations.
- Assuming quality license plate image capture equipment is procured and properly installed, ongoing maintenance cost should be minimal.
- Utility of license plate image capture equipment can be maximized by using the same equipment to validate HOV users by comparing the captured license plate number extracted in near real-time by-lane level optical character recognition (OCR) and matched to a registered HOV list.
- NCDOT/NCTA will have the resources and systems to provide violation processing services at a remote location, including manual review of license plate images, NCSHP license database interface, citation issuance, payment processing and tracking, and evidence package preparation.

- Benefits from existing legislation that requires all outstanding tolls, fines and fees be paid as a condition of re-registering the vehicle used to commit multiple violations.

#### **Automated Enforcement Disadvantages**

- Delivered HOT lane enforcement system must be capable of distinguishing valid single-occupant vehicle and HOV users to simplify the license plate image capture decision to two possible states: authorized and unauthorized user.
- Additional cost incurred for violation processing services. It is common to expect all collected violation fees and fines at least cover all costs incurred by NCDOT/NCTA to operate the subsystem.
- A citation issued to an innocent party could result in a public relations catastrophe, although the probability of such an occurrence is quite small if effective quality control procedures are implemented.
- Restoration of communication loss or repair/replacement of defective in-lane equipment must wait until a period of low traffic volumes, possibly resulting in loss of violation revenue and the ability to identify valid HOV users.
- Requires provisions for handling challenges to issued citations, typically done either through an administrative hearing judge arranged by NCDOT/NCTA or through a civil court proceeding, which increases operating costs.

#### **5.4.1 Transaction Status Indicator Light**

A transaction status indicator light is a LED light powered from a zone controller and activated whenever a valid single-occupant vehicle or HOV transaction is recorded. This beacon is mounted on a proposed cantilever structure pole so that it is visible from upstream of the tolling zone by a NCSHP officer in a patrol car or motorcycle. The duration of the light activation is configurable with a default value, such as two seconds. The patrol officer can use this beacon to determine potential violators corresponding to when no light activation occurs, pending confirmation of the occupants. Since the proposed concept is for HOVs to have a transponder, a transaction beacon will be required to display two distinct light colors or shapes corresponding to either a single-occupant vehicle or HOV status. A single LED display capable of displaying two distinct colors can also provide the required functionality.

It has been observed that daily police activity is not necessary to keep HOT lane violations to an acceptable level of compliance; a program of varied frequency and level of effort has been found to be just as effective. Too much enforcement will degrade the operating performance of a HOT lane facility, while too little will result in customer dissatisfaction and erosion in confidence in the facility. However, the presence of an officer's vehicle in the field, even without actively pursuing violators can be an effective deterrent.



**Figure 5-1: Transaction Status Indicator Light**

### 5.4.2 Violation Enforcement System

Violations in the HOT lanes mean any moving or civil infraction that violates North Carolina General Statutes. Violations most unique to the operation and management of HOT lanes include:

- Toll evasion
- Occupancy infractions
- Buffer crossing

Other moving violations are typically dealt with in a manner similar to any other lane on the freeway system.

#### ***Toll Evasion***

Toll evasion enforcement involves the process of differentiating who has paid and who has violated the I-77 HOT lanes transponder presence/active account requirements. The chosen system is the Violation Enforcement System (VES) for toll evasion<sup>2</sup>.

The VES will require:

- Mandatory registration of all HOT lane users
- Occupancy self-declaration transponders
- VES cameras and lights installed at toll gantries, oriented to capturing images of rear license plates
- LPR for license plate capture images. This system includes image capture, processing, and OCR for processing by the toll integrator.
- On-board mobile tag and account readers for police, if the selected technology can be workable to the satisfaction of NCSHP (system integrator functional requirements are worth including this option).

As a customer travels through the toll zone, the lane controller will verify that the vehicle is equipped with an active transponder and account. If no tag is detected, the license plate will be captured. Any vehicle without an active account will receive a violation notice sent to the registered owner of the vehicle. If the vehicle is registered to a valid account, the LPR will treat the vehicle, be it HOV or single-occupant vehicle, as a single-occupant vehicle and charge the associated toll. HOV vehicles who are charged in this manner may initiate a request to the CSC for a refund; a back-office correction can be made and the user will be assisted in replacing his transponder.

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<sup>2</sup> Current transponders have a track record of working well for electronic toll applications. However, some tags do not have write capabilities, so there is no information on the tag for instant enforcement verification purposes. The current generation of transponders used by some states does not provide any means of determining or declaring vehicle occupancy. Adopting a transponder with switching capabilities will help users self declare. While current technology can be applied to promote a high level of toll evasion enforcement reliability, both buffer crossing and occupancy enforcement must be performed in the field manually by NCSHP under contract.

The VES system will reduce NCSHP's role by eliminating the need for them to provide toll enforcement. To augment the VES system, NCDOT/NCTA will monitor, test, and adopt automated vehicle occupancy verification (AVOV) systems to reduce enforcement presence and exposure upon such a time that the technology has been verified and accepted for general practice.

### ***Occupancy Infractions***

There are currently no new or emerging technologies that can be adapted on HOT lanes to replace on-site enforcement of vehicle occupancy. By introducing switchable transponders and LPR, NCSHP will be able to increase their focus on occupancy enforcement since they will not need to focus on toll evasion. Self-declared HOV vehicles will signal via a beacon above the toll gantry; the beacon will allow NCSHP personnel to identify self-declared HOVs, for which they will then be able to visually verify the occupancy.

### ***Buffer Crossing***

A common moving offense is buffer crossing, where access to the HOT lane is restricted through the use of double-solid lines. Buffer crossing will rely on on-site enforcement presence. Access to and from the HOT lane will be designated, signed and marked. The requirements for use will be posted in vicinity of all access locations. Buffer crossing monitoring may be performed from stationary or roving patrols, and apprehension will be performed on the right side shoulder or off the freeway at the discretion of the officer.

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## 6.0 DESIGN

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This chapter reviews design principles, typical sections, signing and marking concepts, facility access, and lane transitions based on work performed on the Charlotte Regional *Fast Lanes* Study and the I-77 HOV-to-HOT Lanes Conversion Feasibility Study. The chapter provides an overview of the toll system, business rules for calculation of tolls, toll collection and signage procedures, and communications.

### 6.1 Geometric Design of HOT Lanes

#### 6.1.1 Charlotte Regional *Fast Lanes* Study

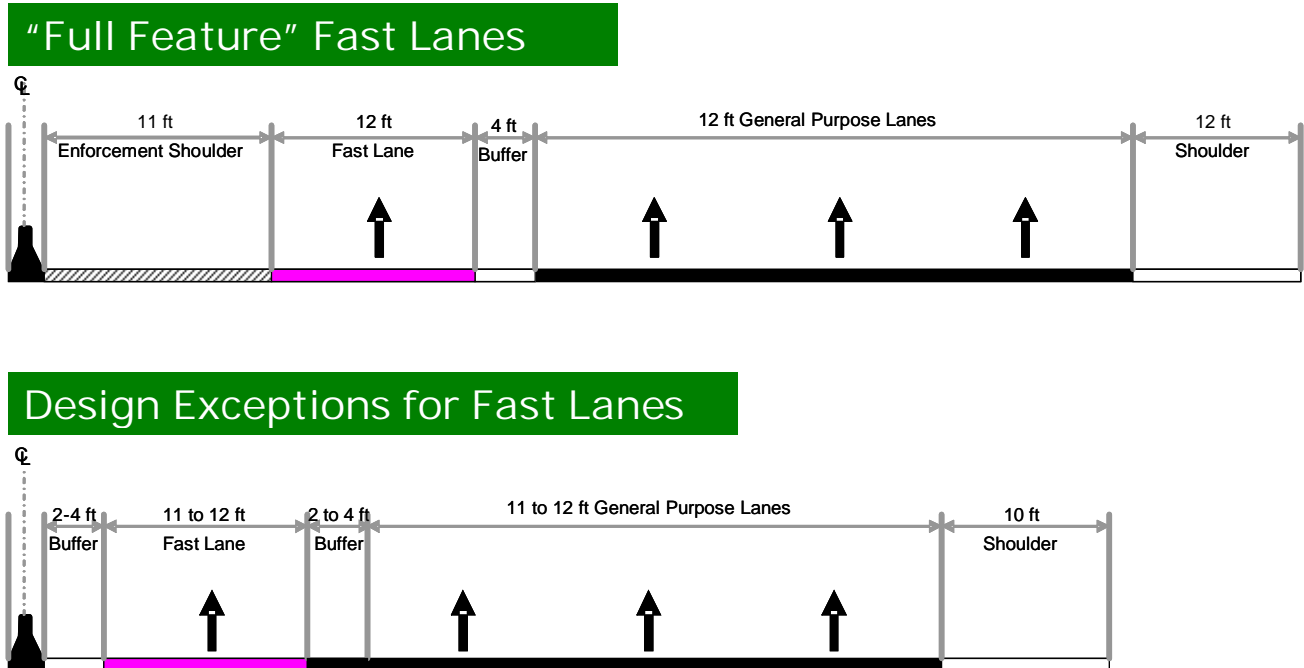
During the Charlotte Region *Fast Lanes* Study, two design approaches were developed for managed (HOV or HOT) lanes:

- “Full feature” using widths provided by NCDOT for shoulders and lanes and for the buffer separation between the HOT lane and the adjacent general purpose lane. This approach requires major widening to provide the new travel lanes and full shoulders where they currently don’t exist. This approach produced ultimate or build-out cost estimates.
- Use of design exceptions where needed or appropriate, consistent with practices employed along a portion of I-77 to implement the HOV lane between I-85 and I-277 (Brookshire Freeway), as well as in many cities around the United States. HOT lane facilities have often been created by converting the inside shoulder to a managed lane and narrowing adjacent lanes so as to provide the benefits of HOT lanes as early as possible without requiring new right-of-way.

**Figure 6-1** compares a “full feature” cross section with the “minimum” or reduced cross section that would be developed on constrained highway segments by allowing design exceptions. **Table 6-1** lists the assumptions for estimating the costs for direct connectors between adjacent freeways. **Table 6-2** summarizes roadway design principles assumed for the “full feature” approach, while **Table 6-3** lists the corresponding assumptions when permissible design exceptions are used. Under the latter approach, widening for new HOT lanes would be minimized as much as possible to remain within the existing paved cross-section or right-of-way. If needed, travel lanes and the inside shoulder would be narrowed, assuming they have not been narrowed previously. In some cases, additional pavement may be required in the existing median or on the right side of the highway. Where there is simply not enough space within the existing right-of-way to allow for a new HOT lane, new right-of-way would have to be purchased and full feature designs would be applicable. Any approach would require approval of the appropriate design or design exceptions by NCDOT and the Federal Highway Administration (FHWA).



**Figure 6-1: Typical Cross Sections  
("Full Feature" and Design Exceptions)**



**Table 6-1: Assumptions for Direct Connectors/ Flyovers**

Evaluation and construction cost estimates for direct connectors were prepared separately from cost estimates for mainline improvements.

- A two-way third level flyover from median to median was assumed for each alternative.
- Depending on available median space, reconstruction of the existing roadway was considered in the estimate. It was assumed that approximately one-half mile would need to be reconstructed to provide sufficient space for the direct connection merging and diverging lanes and median transitions.
- The "design exceptions" alternative was used as the existing condition for the proposed direct connections. Only upstream and downstream structures with significant median space or interchanges and roadway segments that were reconstructed as part of the "design exceptions" alternative were assumed to accommodate the direct connections without major widening or reconstruction.

**Table 6-2: Assumptions for “Full Feature” Design Standard**

**Converting Existing or Future HOV lanes to HOT lanes**

- For I-77 from the I-277 (Brookshire Blvd) interchange to I-485 North, the existing HOV lane could be converted to a HOT lane with modifications to include a minimum separation of four feet between HOT lanes and the general purpose lanes and an increased inside shoulder width to be used as an enforcement shoulder.
- Future proposed projects for I-77 from I-485 North through Iredell County are likely to include an extension of the HOV lanes. It was assumed that an HOV lane would be accommodated in the design with a typical section similar to what exists south of I-485. However, modification of the existing inside shoulder width would be necessary to accommodate the increased enforcement shoulder.
- Where insufficient median width exists, some changes in alignments will be necessary to accommodate the increased enforcement shoulder, standard lane widths and increased separation between the HOT lane and the general purpose lanes.
- New signing, pavement markings and ITS installations would be necessary along the corridor.

**Widening for New HOT Lanes**

- One HOT lane in each direction of traffic flow was assumed for most freeway segments. The only exceptions include I-77 between I-485 South and I-277 (John Belk Freeway) and Independence Blvd from I-485 East to I-277 where two ETL lanes were also analyzed. Additional general purpose lanes were included based on the 2030 LRTPs.
- The proposed typical section includes a minimum of 12-foot lanes, 11-foot enforcement shoulder and a 12-foot outside shoulder. A minimum separation of four feet between a HOT lane and a general purpose lane was assumed. Full continuous enforcement shoulders would be included throughout the corridors.
- With the proposed typical sections, any current deficiencies such as reduced lane and shoulder widths would be brought up to the current design standards.
- This design approach will require widening both in the median (where feasible) and outside lanes. In some cases, this approach will require widening beyond the available right-of-way.
- The estimated right-of-way costs are based on current land use values provided by MUMPO. It was assumed that right-of-way will be required when existing frontage roads are relocated and interchanges are rebuilt.
- Similar to the “design exceptions” assumptions, existing overpasses and interchanges were evaluated to determine if proposed typical section widths could fit within the existing bridge footprint without replacement. If this was not the case, then full replacement of the interchange or overpass was assumed.
- With the exception of locations involving significant widening, it is assumed that existing mainline bridges over roadways, railroads and streams will be widened and the existing vertical clearance requirements can be maintained. Exceptions include locations where two or more lanes plus enforcement shoulders are proposed, or where the existing typical section currently contains a reduced lane and/or shoulder width resulting in additional widening to bring existing lanes up to standard.
- Existing frontage roadways with insufficient separation between the mainline travel lanes would be relocated.
- New signing, pavement markings and ITS installations would be necessary along all alternatives at an estimated cost of \$2.5 million per directional mile.

**Table 6-3: Assumptions for “Design Exceptions” Approach**

<p><b>Converting Existing or Future HOV lanes to HOT Lanes</b></p> <ul style="list-style-type: none"><li>• For I-77 from I-277 (Brookshire Blvd) interchange to I-485 North, the existing HOV lane will be converted to a HOT lane without major geometric modifications. Existing lane widths and shoulder widths will remain the same.</li><li>• Future proposed projects for I-77 from I-485 North through Iredell County may include an extension of the HOV lanes. It was assumed that an HOV lane would be accommodated in the design with a typical section similar to what exists south of I-485.</li><li>• No changes in roadway alignments, lane widths and shoulder widths will be made for this conversion.</li><li>• New signing, pavement markings and ITS installations would be necessary throughout the I-77 HOV conversion.</li></ul>
<p><b>Widening for New HOT Lanes</b></p> <ul style="list-style-type: none"><li>• One additional HOT lane will be added in each direction for each alternative. No additional general purpose lanes are assumed, and if programmed, are not included in cost estimates.</li><li>• Proposed projects requiring bridge replacement would be designed to accommodate the additional width required for HOT lanes implementation. This incremental cost difference associated with widening is included in the cost estimate. These projects include future widening of I-85 north of I-485 Northeast, US-74 (Independence Boulevard) east of Albemarle Road, and I-485 (Southern Outer Loop widening).</li><li>• Widening is proposed without any reduction in existing lane widths in areas where sufficient median width is available to accommodate widening. Where this is not the case, existing lane and shoulder widths are proposed to be reduced to fit within the existing roadway and/or right-of-way footprint with limited additional pavement width needed. It is assumed that for such pinch points, lane widths could be reduced to a minimum of 11 feet and inside shoulder widths to a minimum of two feet. The buffer width between the HOT lane and the general purpose lanes could be reduced to a minimum of two feet. Outside shoulder widths could be reduced to a minimum of 10 feet.</li><li>• Only in cases where the existing footprint underneath the existing bridges or interchange bridges could not accommodate the reduced typical width would full bridge or interchange replacement be assumed.</li><li>• Widening of existing mainline bridges would be based on the proposed roadway typical section. Any widening on mainline existing bridges is assumed to meet all vertical clearance requirements.</li><li>• With the modified lane widths and reduced shoulder widths, the inside (median) shoulder could possibly require reconstruction to remove the existing shoulder break, widening in areas where full depth pavement currently does not exist and construction of additional drainage features to reduce water spread along the inside barrier wall. Due to these uncertainties, minimal reconstruction is assumed along the existing inside shoulder to accommodate any lanes shifting inward. In addition, the cost of milling and/or overlaying the existing roadway to remove the existing markings is included in this estimate where applicable.</li><li>• Limited spot enforcement shoulders are assumed in areas where sufficient median width is available. No adjustments in the mainline travel lane geometry will be made to accommodate these enforcement areas.</li><li>• Most alternatives will fit within existing right-of-way. The exception includes I-77 south of I-277 (Brookshire Freeway) where reconstruction of the existing roadway will require new right-of-way.</li><li>• All existing frontage roads will retain their current configurations and widths.</li><li>• New signing, pavement markings and ITS installations would be necessary for all alternatives, at an estimated cost of \$2.5 million per directional mile.</li><li>• No lane separation treatment is assumed for separating the HOT lane and free lanes.</li></ul>

### **6.1.2 I-77 HOV-to-HOT Lanes Conversion Feasibility Study**

The design principles used in the I-77 HOV-to-HOT lanes conversion feasibility study are similar to those employed along the existing HOV facility south of I-485 as well as HOT lanes conversions in other locations around the country.

### Typical Section

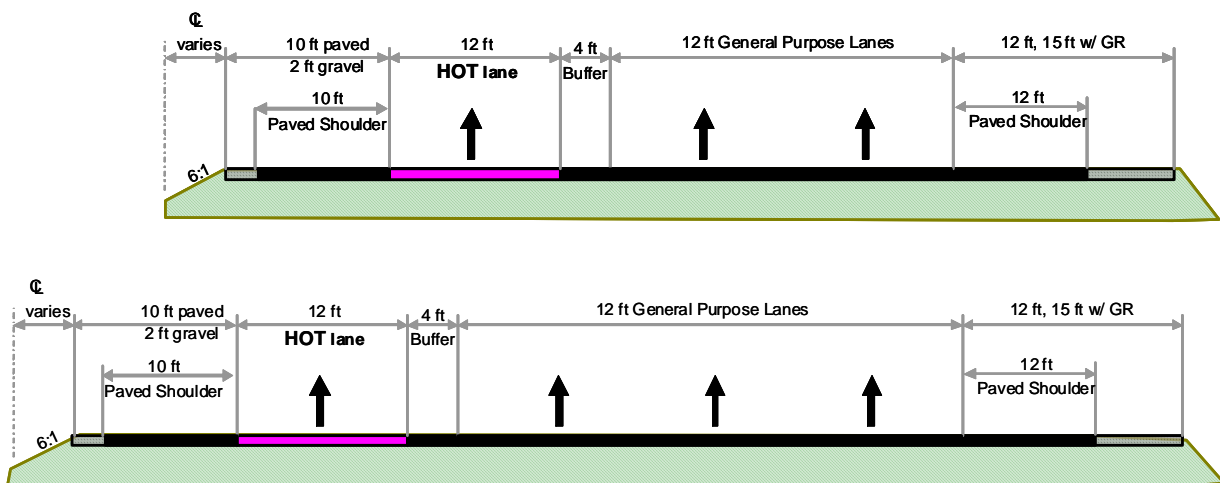
The HOT and general purpose lanes would typically be 12-feet wide with a 4-foot painted buffer between the HOT and general purpose lanes. The inside (left) paved shoulder width would be 10 feet while the outside (right) paved shoulder width would be 12 feet. In this example no reductions from full design widths would be necessary. **Figure 6-2** shows typical sections for two build alternatives analyzed for I-77.

For the I-77 example, delineators would not be used in the buffer area to separate the HOT lanes from general purpose lanes because of maintenance costs and close proximity to high-speed traffic, although delineators have proven to work well in other HOT lane project settings nationally.

### Trade-offs in Accommodating Design Principles

Safety is a major consideration when evaluating HOT lane facility design elements. The available right-of-way and median of I-77 generally allow for all desirable design components to be included. These features include 12-foot lane widths, inside breakdown shoulders and buffer separation to address the potential speed differential between HOT and general purpose lanes. North Carolina State Highway Patrol (NCSHP) and Charlotte police officers have safely used the 10-foot inside shoulder for enforcement purposes since the HOV lanes opened in 2004. In isolated segments, particularly on the south end of the corridor, design exceptions are currently in effect. Pre-existing trade-offs made when the HOV lane was implemented between I-85 and Brookshire Boulevard (I-277) include narrower lanes, no buffer separation and a narrower inside shoulder. These trade-offs were deemed to be acceptable until such time that widening could be undertaken to return lane and shoulder widths to full standards.

**Figure 6-2: Typical HOT Lane Cross Section**

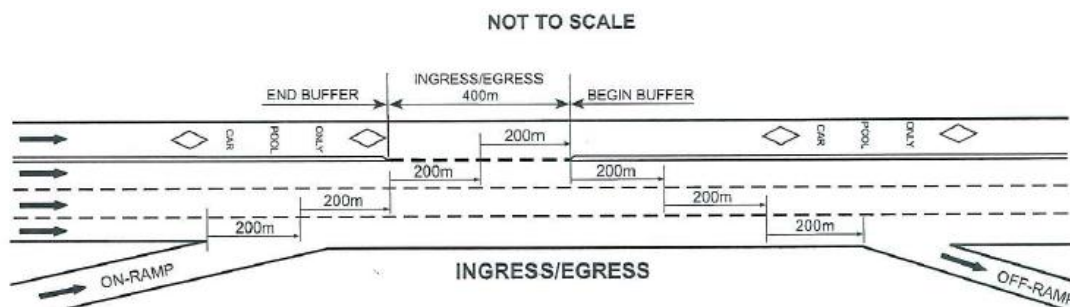


## 6.2 HOT Lanes Access

As noted in Section 4.3 the operation and access policy will influence access design. During the I-77 HOV-to-HOT Lanes Conversion Study, it was decided that intermediate access to the I-77 HOT lanes would be similar to the approach taken for the HOV lanes.

Motorists would be permitted to enter and exit the HOT lane only at designated breaks in the solid pavement markings. These locations coincide with operational settings that match major ingress and egress demand to and from right side ramps, and would be located to allow for a minimum of 600 feet and desirably 1000 feet per general purpose lane for merging and weaving between the left and right sides (**Figure 6-3**). Intermediate access would typically be spaced about every two to three miles, but could be much longer depending on trip patterns in a corridor. Obviously, the longer the spacing, the lower the cost to add tolling infrastructure. The length of the intermediate access may vary based on anticipated demand, but should be considered to be about 1500 feet in length and no less than 1200 feet.

**Figure 6-3: Typical Weave Criteria for Intermediate Access Locations**



## 6.3 Signing and Pavement Markings

As part of the planning for the I-77 HOT lanes, it was decided that signing would be located one mile and half-mile in advance of intermediate access locations to the HOT lanes to inform motorists of access points. **Figure 6-4** shows the sequence of signs within the access zone, reflecting traffic moving from right to left. A sign displaying the prevailing toll rate for up to two downstream destinations would be located immediately upstream of the access opening. Beyond the access opening, a toll gantry would record the transaction. Just beyond the toll gantry, a sign would display downstream exits and approximate mileage. Each access opening would typically facilitate both ingress and egress movements with the HOT lane. Based on traffic simulations performed, an open weave area appears to work for most intermediate access treatments. If more than one directional HOT lane is planned, weave or transition lanes between the parallel roadways may be justified. Regulations would restrict access except at designated openings.

HOT lanes signing would reflect the latest MUTCD (2009 or as amended). As such, if the project is an HOV conversion, the sign and pavement marking diamonds would be removed, and the facility would be called "Express Lanes." Regulatory signing would continue to be black on white, with guide signing white on green. Banners would be applied to all

“Express Lane” signing to distinguish communication to these users from general traffic. Example signing is shown in **Figure 6-5**.

**Figure 6-4: Typical Intermediate Access**

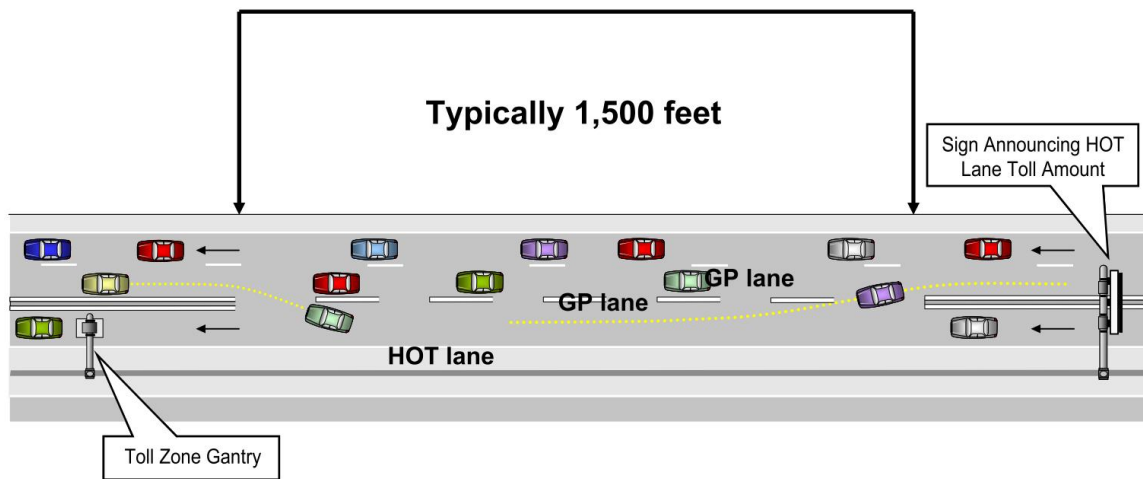
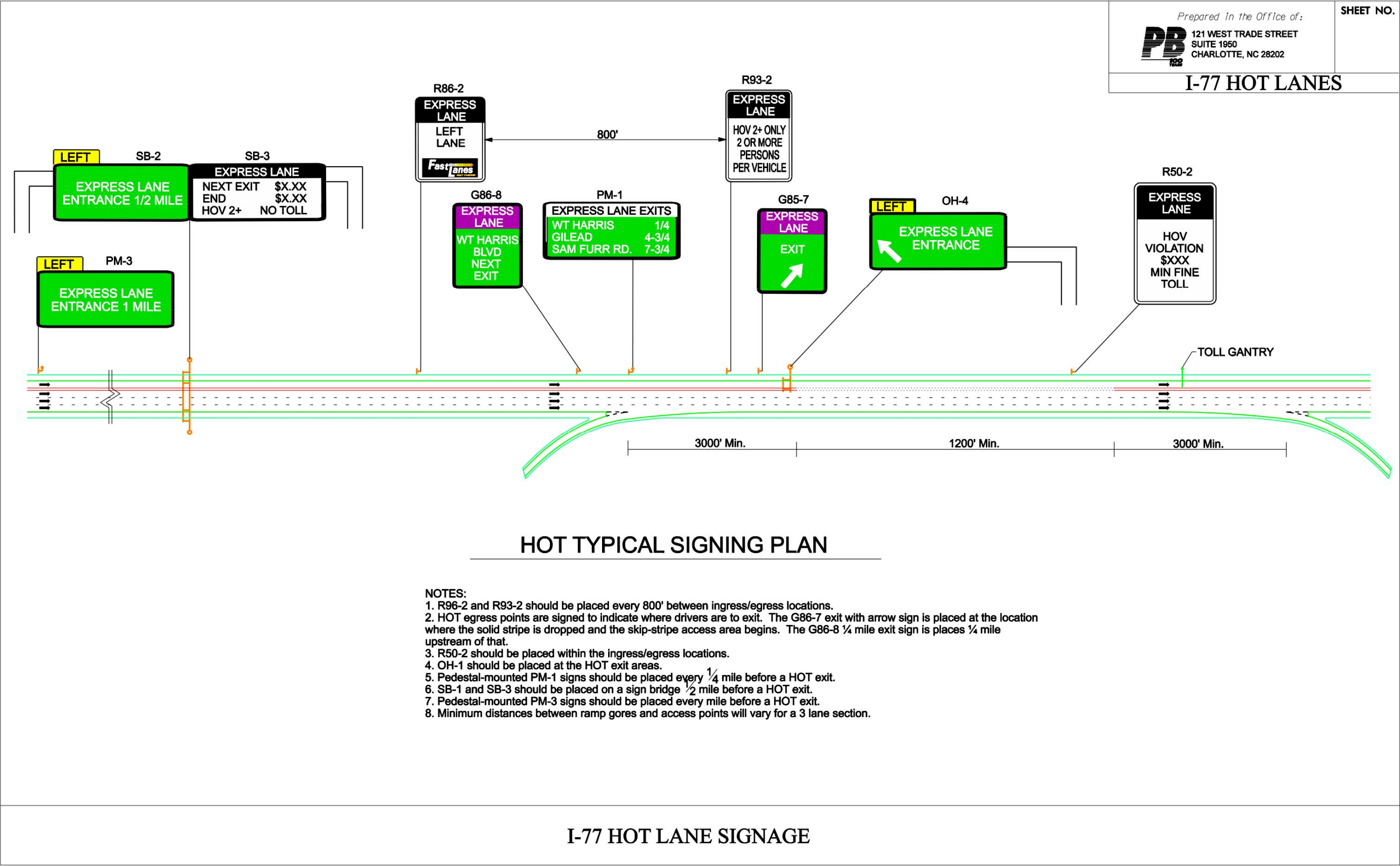


Figure 6-5: Example Express Lane Signing





## 6.4 Electronic Toll Collection (ETC) System

The toll collection system for a HOT lanes installation must be compatible with other toll facilities in the region and state, while also being responsive to the unique user requirements. These requirements relate to the design with rather unlimited opportunity for violators to enter and exit the lane at will, and a potential need to adjust tolls dynamically by time of day for each segment of the roadway. Furthermore, the system may also need to account for stratifying tolls sometime in the future to allow carpools with two or more occupants to use the lanes for a discounted toll if their numbers eventually overwhelm HOT lane capacity.

Vehicle detection would be typically provided from the side of the facility or overhead, and would need to include the innermost general purpose lane if the tolling algorithm is intended to ascertain the comparable speeds in both roadways to determine the requisite toll.

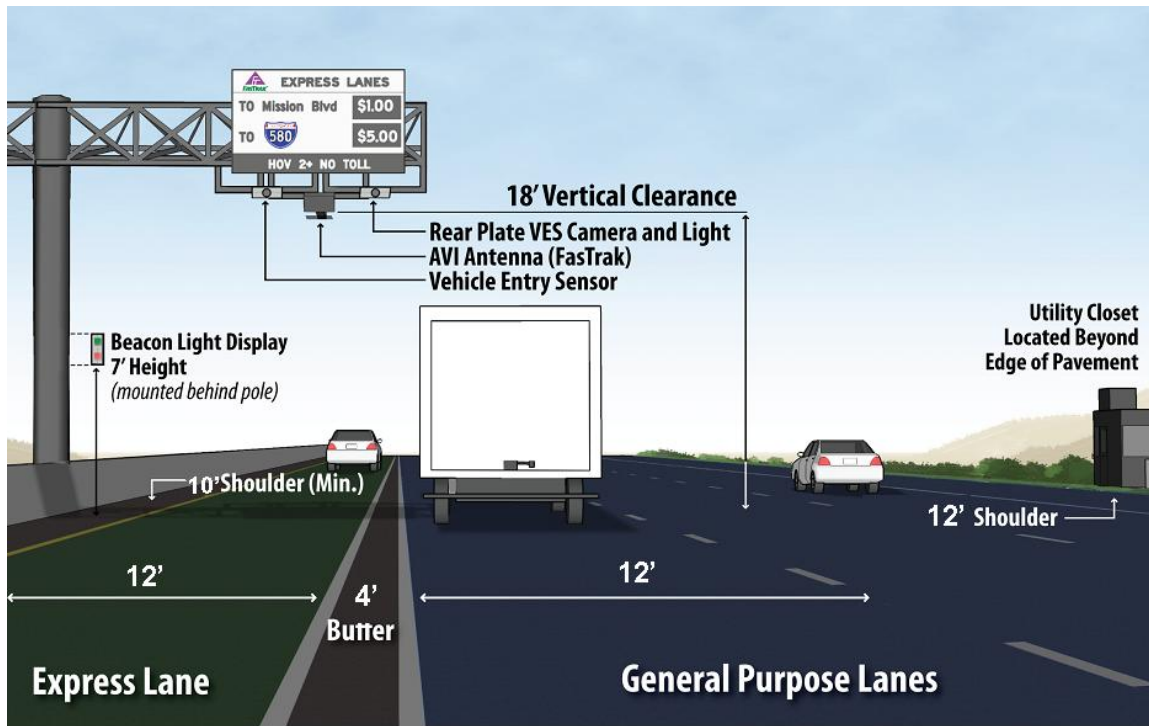
The footprint of the system will have to extend into the general purpose lanes for support structures and traffic monitoring, among other needs. This requirement has a cascading effect upon maintenance and the ability to access signing and equipment without lane closures, to the degree practical. For example, this system will include automatic vehicle identification (AVI) readers that extend over not only the HOT lane, but also the leftmost general purpose lane. This is done in order to separate vehicle transponders to be tolled.

Upstream of the next entrance to the HOT lane, a gantry (either single column cantilever or facility-span) will extend across the HOT lane and left-most general purpose lane. Co-location of AVI antennas on the same gantry substantially minimizes the chance of error-based reads (such as a general purpose lane user being misread as a HOT lanes customer). AVI antenna are installed over the HOT lane and left-most general purpose lane. Additionally, a variable message sign (VMS), positioned over the general purpose lane, will advise the traveler of the toll rate in effect and total cost to select downstream destinations. At each toll zone, the gantry includes lighting and cameras for a rear-facing Violation Enforcement Systems (VES), as shown in **Figure 6-6**. The AVI will signal to the back-office the initiation of a potential trip record for the transponder-equipped vehicle, with a tag associated with the toll rate active at the time of the initiation. This is considered a first-read event, with all subsequent events associated with this trip record. If the driver chooses to enter the HOT lane, then the last-read event (upon exit) is used to create a trip pair with calculation of total toll cost based upon the prevailing toll rate at the time of the first-read event. Each read event records the transponder identification number, license plate number (in select toll zones with Violation Enforcement Systems), date, time, and location identification number. If the driver elects to remain in the general purpose lane, no toll record will be recorded for the trip. The central processing system will record the next event in the general purpose lane and determine that the vehicle did not use the lane. Each subsequent pass reopens the potential trip record creating a trip assembly for the purposes of calculating the toll.

Travel time data for customers and non-customers will be maintained in order to establish travel times and average speeds between read events. In effect, every transponder-equipped vehicle that successfully completes a read-event pairing serves as a probe vehicle for travel times. This data may augment additional traffic detection and sensing equipment, providing feedback to the dynamic price setting subsystem.



**Figure 6-6: Sample Toll Zone**



In addition to toll evasion enforcement, the VES also augments the toll collection system to ensure completeness of data. If a transponder is inaccurately read, or if there is missing data after a first-read event, the VES will be used to substitute the data. Optical character resolution (OCR) is performed on license plate capture images for comparison and verification of account status for the last recorded position and first unrecorded position, to ensure a completed trip record (and toll charge) is performed. Without conducting the VES comparison, inaccurate entry and exit reads may occur, with inaccurate toll charges assessed. Conversely, if no first-read event is recorded on the general purpose lanes – and the system only shows the account having initiated within the HOT lane – then the entry point must either be estimated based upon VES data (which may be subject to error) or only those points with successful data transactions recorded (which would yield revenue leakage).

## **6.5 Communication Network and Electrical Requirements**

Along the I-77 corridor, it was determined that a separate fiber optic conduit would be installed to serve as the communication link between tolling and enforcement equipment and back office monitoring and processing. While this link may be able to use NCDOT traffic monitoring infrastructure in the field (subject to a value engineering assessment), cost estimates at this feasibility stage assumed a separate dedicated conduit and independent communication system. This assumption was also based on the expectation that a separate maintenance provider or system integrator will be responsible for a high level of functional reliability for the installed communication system.

In the case of I-77, existing nodes on the NCDOT fiber optic cable backbone provided communication services to some CCTV cameras installed for surveillance and represented an opportunity for transmitting video and data to the MRTMC and NCDOT/NCTA Central Processing (via an interconnection to the public network). Use of the existing ITS infrastructure fiber backbone would allow allocation of at least one dark fiber that may be used in conjunction with a local carrier's network for linking a transponder read zone with NCDOT/NCTA Central Processing. Alternatively, the use of current ITS equipment (e.g. VMS, CCTV), mounted to a pole or cantilever structure, is an opportunity to mount a transceiver, radio or antenna to support wireless communication.

The utility company having a franchise agreement to provide electrical service in the vicinity of the I-77 HOT lanes facility would need to be determined and contacted during the design phase to discuss the need for service at the toll zone, read zones, pricing sign and traffic controller locations. Coordination with utility companies is necessary to determine the availability of existing transformers that can service the HOT lane field equipment at a lower cost than installing a new transformer and the associated overhead or underground electrical cabling by the utility company. Routing electrical cable from an existing electrical panel installed in conjunction with a VMS or CCTV surveillance camera site located within the I-77 project limits to one or multiple HOT lane equipment sites requiring power should be investigated. If NCDOT allows a connection to this panel, the cost associated with using this source should be compared to the cost of obtaining electrical service from the utility company's new or existing source through which electrical service is delivered to each HOT equipment site that requires power. If electrical service is obtained from the utility company, a transformer that steps the available voltage down to 120/240 VAC is required to power the HOT equipment at each site. It is envisioned that unit ductwork will be installed by the contractor to route cable from either an existing electrical panel or the utility company's transformer to a particular site. The utility company providing the service or a licensed electrical contractor would make approved connections to the designated transformer(s).

## **6.6 Toll Collection System Configuration**

HOT lane facilities commonly have multiple toll zones where transactions are recorded and sent to a central processing server where transaction records containing the same transponder ID are combined into a trip, subject to a maximum time difference on consecutive transactions. The trip is then assigned a price that the system determines the user viewed when entering the facility, usually by applying rules that result in the lesser of two possible tolls displayed closest in time to the system calculated entry time. Transaction records are built within the field tolling system and sent to Central Processing at the Data Center in near real-time. When there are multiple toll zones, a trip building process is an important component in the field that can reduce cost with one transaction fee incurred per user trip.

## **6.7 Vehicle Detection and Toll Collection Subsystem**

Accurate vehicle detection is required to generate raw traffic data for input to a pricing algorithm that continuously calculates the price for single-occupant vehicles to use the facility such that free-flow conditions are maintained. For I-77 HOT lanes, new vehicle detectors will need to be installed in each direction at about half-mile spacing. Agencies have implemented a HOT lane system that collects traffic data in the general purpose lanes for the purpose of pricing the HOT lanes based on time saving relative to the general purpose lanes or as a means of validating HOT lane traffic data by correlating traffic trends. The later process also adds redundancy to the system so operations can continue if

controller communications for the HOT lane fail. Given a HOT lane pricing scheme objective of maintaining free-flow conditions, three alternatives for supplementing and adding redundancy to traffic data collected in the HOT lanes are:

1. Install non-intrusive vehicle detectors (e.g., RTMS) to collect traffic data in all travel lanes at locations that are coincident with each HOT lane vehicle detector,
2. Install a read zone in each direction and use vehicles with valid transponders as probes to calculate travel time and speed in the HOT lane between the toll and read zones.
3. Rely on existing vehicle detectors installed in the general purpose lanes to extrapolate travel conditions in the HOT lane.

The advantages and disadvantages of these three alternatives are presented in **Table 6-4**.

**Table 6-4: Advantages and Disadvantages of Vehicle Detection and Toll Collection**

Alternative	Advantages	Disadvantages
1	Traffic data can be simultaneously collected in each general purpose lane and the HOT lane by a single sensor, providing a means to validate and supplement the vehicle detector data collected in the HOT lanes, particularly important when vehicle detector station (VDS) data is not available for input to the pricing process.	Studies have shown some degradation in performance of radar based sensor technology in slow moving congested flows that may result in over counting vehicles (note: in-pavement vehicle detectors tend to undercount in bumper-to-bumper traffic)
	A non-intrusive, roadside-mounted vehicle detector eliminates any disruption to traffic, which is inherent to replacing an in-pavement sensor and associated wiring.	Radar based sensors may need to be periodically recalibrated to correct drift in accuracy.
	Collection of general purpose lane traffic data allows the validation of traffic speed and density trends calculated in the HOT lane by comparing to calculated traffic data trends in the general purpose lanes, which are a precursor.	Poles used to mount a radar based sensor need to be protected by guardrail or barrier, assuming installation off the right shoulder in each direction of travel.
		Power and communication is required for each radar based sensor installed just beyond the outside shoulder in each direction of travel.

**Table 6-1: Advantages and Disadvantages of Vehicle Detection and Toll Collection (cont.)**

<b>2</b>	In addition to providing a reliable means of calculating travel time and speed when combined with toll zone data that can be input to the pricing process, a read zone is expected to eliminate cross lane reads and support an advisory sign, where applicable.	Maintenance of the read zone equipment installed on the cantilever structure requires traffic control devices and likely the closing the HOT lane.
	Calculated traffic data is immune to the speed and density of the traffic stream, unlike the majority of commercial vehicle detectors.	Requires boring/jacking conduit under the GP lanes and Express Connector to route power and communication from a roadside cabinet to a cantilever or "T" structure.
	Because of high accuracy, lower volumes of transponder-equipped vehicles will not degrade performance, assuming the presence of at least one such vehicle during the pricing change interval.	Structures and roadside cabinets add clutter to the facility's appearance. (Note: This can be mitigated by a "T" structure which reduces by half the number of structures and roadside cabinets; maximizing utility of the structure by mounting an advisory sign reduces clutter for all structure types)
<b>3</b>	Avoids incurring any additional cost to install detectors for validating HOT traffic speed and density trends by comparing to the same trends in the general purpose lanes based solely on VDS installed within the project.	Existing vehicle detectors (loops) are only located at the limited locations
	By maintaining an historical moving average of scale factors derived by dividing HOT traffic statistics by general purpose lane traffic statistics during weekday/weekend peak, shoulder and off-peak periods, general purpose lane traffic data can be adjusted for input to the pricing process when HOT traffic data is unavailable.	Maintenance of the existing general purpose lane vehicle detectors requires traffic control devices to temporarily close a lane.
	Existing health of the vehicle detectors installed within the project is not 100 percent, so reliance on these is problematic.	Requires center to inside general purpose lane VDS data within the project to be parsed by NCDOT/NTCA prior to input to a process within the pricing module.
		Calculation of traffic data trends for both general purpose lanes and HOT lanes by a process within the pricing module over configurable time periods adds complexity to the software. Converting historical general purpose lane trends to HOT lane pricing module input data for discrete traffic periods when the facility VDS is not available further adds to complexity.

## **6.8 Vehicle Data Collection, Communication and Processing**

To successfully implement dynamic pricing on the I-77 HOT lanes project, new VDS would have to be installed at close spacing to accurately measure facility speed and density for input to a dynamic pricing algorithm that continuously calculates single-occupant vehicle pricing. The objective of the pricing is to maintain free flow conditions along the HOT lane discouraging users of single-occupant vehicles from entering the facility as speeds decrease and densities increase. A preferred approach is either to 1) collect HOT lane traffic data using vehicle detectors connected to a roadside traffic controller installed at each station, from which the raw data is transmitted via a leased line from a local carrier to the local data center, where it is pre-processed for input to the pricing algorithm; or 2) collect HOT lane traffic data using vehicle detectors connected to a roadside traffic controller installed at each station and using point-to-point wireless communications (i.e., by means of a laser or microwave solution not requiring a FCC license) to a remote facility, where the raw data is routed to the data center via an existing T1 channel leased line from a local exchange carrier.

Maintenance of tolling and enforcement systems requires specialized attention, which may be specific in nature to the technology deployed by the tolling integrator. This technology, though, may be present outside of the roadway right-of-way. For example, tolling algorithms require a significant amount of detector data across multiple lanes of traffic (HOT lanes and general purpose lanes) in order to operate effectively. Given constrained design, and an inability to provide for maintenance concurrent with active operations, a loss in operation may mean either loss in revenue or express lane availability, each with their own consequences for mobility, revenue and customer satisfaction. To avoid these consequences, maintaining these tightly integrated systems require a high level of reliability and field maintenance.

In most situations, tolling and enforcement systems may be maintained by the tolling integrator, especially to the extent that any loss in equipment or procedural availability will have an impact upon performance. As a result, the integrator has every interest to maintain adequate preventative maintenance in order to avoid demand-response maintenance. In the future, NCDOT/NCTA may elect that tolling system maintenance may be operated by a third-party provider under a separate performance contract from that of the tolling integrator. However, even with augmented funding, NCDOT maintenance forces could be limited with respect to accommodating additional maintenance needs or a higher standard of maintenance compliancy, at least for functions deemed critical to the intended HOT lanes performance objectives.

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## 7.0 REVENUE FORECASTING

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This chapter summarizes the approach used in Charlotte for estimating potential HOT lanes revenue at both the **regional** (Charlotte Regional *Fast Lanes* Study) and **corridor** (I-77 North between Charlotte and Davidson) levels.

### 7.1 Regional *Fast Lanes* Study

As appropriate for a first-order assessment of a *Fast Lanes* network at a regional scale, simplified, yet conservative, approaches to forecasting revenues were applied. Revenue projections were generated by a tolling model which builds upon forecasts from the Metrolina regional travel demand model.

#### 7.1.1 Approach for Revenue Projections

Toll revenues were dynamically optimized on a five-minute basis for individual corridor segments for the weekday morning peak, midday, afternoon peak and evening periods. Annual revenue forecasts reflected estimates of average weekday volumes and weekend performance using weekday-to-weekend factors from other cities in the US.

From the modeling results, different revenue and toll estimates were generated by varying four key dimensions:

- **Pricing objective.** HOT lanes can be operated to achieve a variety of different objectives. Some facilities might be operated to maximize toll revenues, which is appropriate when the HOT lane facility must cover its capital costs. Other facilities that are not financially constrained can be operated to maintain a target level of service or to minimize aggregate travel time costs for commuters within a corridor or for the overall network. Tolls were established in the Charlotte Region *Fast Lanes* Study to 1) maximize toll revenues, and 2) minimize the aggregate dollar value of time costs in each corridor. For both scenarios, the managed lane was limited to carrying no more than 1,600 vehicles per hour per lane, even though other studies in the US have applied an operational threshold of up to 1650.
- **Carpool policy.** Tolls were estimated for these policy scenarios – HOV 2+ free, HOV 3+ free, and all users pay.
- **Input vehicle volumes.** Vehicle volumes used to generate the revenue forecasts from the tolling model were derived from Metrolina travel demand model runs: 1) where the current HOV 2+ free policy would be in effect for the HOT lanes (HOV 2+ network run), and 2) where the managed lane would be operated as general purpose lane (unrestricted use network run). The difference between the unrestricted and HOV model numbers provided an upper limit of the maximum number of single-occupancy vehicles that would use the managed lane depending on traffic condition, including HOT lane pricing in effect at that point-in-time.
- **Year of operation.** Modeling was completed for two planning years, 2013 and 2030.

### 7.1.2 Comparison of Toll Estimates to Revenue Projections for Other Cities

The tolling model used in the Charlotte Region *Fast Lanes* Study has been used to predict revenues for other HOT lane projects in the United States. **Table 7-1** summarizes Charlotte revenue per lane mile in order to facilitate comparisons with forecasts from other cities. **Table 7-2** and **Table 7-3** provide estimates of forecasted toll levels per mile for the morning and afternoon peak for the various modeling assumptions used in the Charlotte study. **Table 7-4** summarizes the tolling model forecasts for five other metropolitan areas. A comparison of these results with the Charlotte revenue forecasts indicates that:

- The proposed I-15 HOT facility in Salt Lake City is projected to provide slightly greater revenues per mile than Charlotte's HOT lanes. Expected tolls would also be higher on that facility.
- The proposed San Francisco-Oakland (Bay Area) HOT lane system includes interconnected facilities operating in one of the most congested metropolitan areas in the country. The proposed I-680 HOT lane shown in **Table 7-4** is expected to be constructed before the rest of the Bay Area network is developed. In keeping with the respective levels of congestion, revenues per lane mile and average peak period toll charges are much higher for the proposed HOT lanes in the Bay Area than predicted in this study for Charlotte.
- The tolling model was used to forecast revenues for the I-394 HOT facility in Minneapolis for three pricing objectives. Similar to observations made with toll modeling for this study, the revenue forecasts for I-394 depend greatly on the selected pricing objective. The actual revenues for the I-394 facility have been closely replicated by the tolling model. The Minneapolis HOT lane facility is the most similar to the proposed Charlotte HOT lane network of all locations where the tolling model has been used.
- As part of a study of widening SR-217 in Portland, the tolling model was used to estimate revenues for a short express lane facility on that freeway. The estimates for the Portland freeway fall within the range of forecasts obtained for the scenario of "everyone pays" to use *Fast Lanes* in the Charlotte region in 2013.

**Table 7-1: Revenue Estimates per Lane Mile (2008 Dollars)**

Travel Time Cost Minimization Objective				
Policy	Unrestricted Network Run		HOV 2+ Free Run	
	2013	2030	2013	2030
HOV 2+ Free	\$62,000	\$159,000	\$17,000	\$30,000
HOV 3+ Free	\$118,000	\$339,000	\$48,000	\$156,000
All pay	\$148,000	\$437,000	\$66,000	\$225,000
Revenue Maximization Objective				
Policy	Unrestricted Network Run		HOV 2+ Free Run	
	2013	2030	2013	2030
HOV 2+ Free	\$74,000	\$178,000	\$21,000	\$35,000
HOV 3+ Free	\$209,000	\$518,000	\$87,000	\$228,000
All pay	\$362,000	\$923,000	\$174,000	\$497,000

**Table 7-2: Estimated Tolls per Vehicle-Mile (AM Peak) (2008 Dollars)**

<b>Travel Time Cost Minimization Objective</b>				
<b>Policy</b>	<b>Unrestricted Network Run</b>		<b>HOV 2+ Free Run</b>	
	<b>2013</b>	<b>2030</b>	<b>2013</b>	<b>2030</b>
HOV 2+ Free	\$0.07	\$0.23	\$0.03	\$0.09
HOV 3+ Free	\$0.06	\$0.18	\$0.03	\$0.10
All pay	\$0.06	\$0.18	\$0.03	\$0.09
<b>Revenue Maximization Objective</b>				
<b>Policy</b>	<b>Unrestricted Network Run</b>		<b>HOV 2+ Free Run</b>	
	<b>2013</b>	<b>2030</b>	<b>2013</b>	<b>2030</b>
HOV 2+ Free	\$0.12	\$0.29	\$0.05	\$0.10
HOV 3+ Free	\$0.27	\$0.59	\$0.12	\$0.27
All pay	\$0.48	\$1.10	\$0.24	\$0.62

**Table 7-3: Estimated Tolls per Vehicle-Mile (PM Peak) (2008 Dollars)**

<b>Travel Time Cost Minimization Objective</b>				
<b>Policy</b>	<b>Unrestricted Network Run</b>		<b>HOV 2+ Free Run</b>	
	<b>2013</b>	<b>2030</b>	<b>2013</b>	<b>2030</b>
HOV 2+ Free	\$0.06	\$0.16	\$0.02	\$0.05
HOV 3+ Free	\$0.05	\$0.14	\$0.03	\$0.08
All pay	\$0.05	\$0.13	\$0.03	\$0.08
<b>Revenue Maximization Objective</b>				
<b>Policy</b>	<b>Unrestricted Network Run</b>		<b>HOV 2+ Free Run</b>	
	<b>2013</b>	<b>2030</b>	<b>2013</b>	<b>2030</b>
HOV 2+ Free	\$0.10	\$0.22	\$0.03	\$0.07
HOV 3+ Free	\$0.22	\$0.47	\$0.10	\$0.23
All pay	\$0.39	\$0.89	\$0.21	\$0.50



**Table 7-4: Summary of Recent HOT Lanes Studies Results that Used Tolling Model**

	I-15 HOT Lanes, Salt Lake City, UT	Bay Area (San Francisco-Oakland, CA) HOT Lane Network Study	I-680 in Northern California	I-394 MnPASS HOT Facility Minneapolis, MN	US-217 in Portland, OR			
Facility Characteristics								
Priced Lane Miles	I-64 to I-73 depending on network	488.1	488.1	15.2	21.2	21.2	21.2	10.5
Carpool Policy	HOV 2+ Free	HOV 2+ Free	HOV 3+ Free	HOV 2+ Free	HOV 2+ Free	HOV 2+ Free	HOV 2+ Free	Everyone pays
Pricing Objective	Revenue Max	Min Travel Cost	Min Travel Cost	Revenue Max	Revenue Max	Min Travel Cost	Maintain Target LOS	Maintain Target LOS
Max HOT Lane Vehicles/ Lane/ Hour	None	1600	1600	1550	None	None	1450	850
Pricing Approach	Dynamic	Dynamic	Dynamic	Dynamic	Static	Static	Static	Static
Year Modeled	2015	2015	2015	2010	2005	2005	2005	2014
Dollars	2000	2005	2005	2006	2005	2005	2005	2004
Hours/ Days of Operation	24 / 7	24 / 7	24 / 7	24 / 7	9 / 5	9 / 5	9 / 5	24 / 7
Directional	No	No	No	Yes	Yes	Yes	Yes	No
Revenue and Toll Levels								
Annual Revenue per Lane Mile	\$70,000 to \$160,000	\$350,000	\$900,000	\$320,000 to \$440,000	\$65,000	\$25,000	\$30,000	\$290,000
Annual Peak Period Toll per Mile	\$0.10 to \$0.32	\$0.24	\$0.21	\$0.33 to \$0.37	\$0.16	\$0.03	\$0.06	\$0.37
Source: (1) I-15 HOT Lane Study Memo dated, 12/6; (2) Existing and Funded Network Results, 10/31/06; (3) Memo to ACCMA, 3/31/06; (4) Memo titled "Analysis of I-394 Hot Lane Facility", 11/2005.								

### 7.1.3 Comparison of Toll Projections to Actual Revenues in Other Cities

In recent years, several HOT lane facilities have been implemented. **Table 7-5** summarizes operating conditions, revenue and toll levels for three HOT facilities currently in service:

- I-394, which was discussed in the preceding section
- I-15 in San Diego, California
- SR-91 in Orange County, California

**Table 7-5: Summary of Facility Characteristics, Revenue and Tolls for Existing HOT Lane Facilities**

	<b>SR-91 (Orange County, CA)</b>	<b>I-15 (San Diego, CA)</b>	<b>I-394 (Minneapolis, MN)</b>
<b>Priced Lane Miles</b>	40 miles (2 lanes in each direction for 10 miles)	16 miles (2 reversible lanes for 8 miles)	21.2 miles (1 lane in each direction for 8 miles plus 2 reversible lanes for 3 miles)
<b>Carpool Policy</b>	HOV 3+ get 50% discount during peak periods, free during off-peak	HOV 2+ ride free	HOV 2+ ride free
<b>Pricing Approach</b>	Static	Dynamic	Dynamic
<b>Hours/ Days of Operation</b>	24 / 7	13.3 / 5	9 / 5
<b>Directional</b>	No	Yes	Yes
<b>Annual Revenue per Lane Mile (approximate)</b>	\$1,245,000	\$125,000	\$40,000
<b>Annual Peak Period Toll per Mile (approximate)</b>	\$0.20 to \$0.96	\$0.06 to \$1.00	\$0.10 to \$0.45

Tolling model results for the Charlotte HOT lane system in 2013 represent the closest comparison to the results for these three facilities. The following conclusions can be made from comparison of Charlotte model results to these locations:

- A comparison of Charlotte's results under a HOV 2+ carpool policy with information from San Diego and Minneapolis indicates that Charlotte would generate less revenue per lane mile than I-15 and about the same level as I-394. Forecasts of peak period tolls are generally lower than what is being charged on these two HOT lanes.
- The SR-91 HOT lanes are generating much higher revenue per lane-mile than the forecasts for the Charlotte system under any operating policy or set of assumptions. The tolls per mile on SR-91 also are significantly greater than those forecast for proposed Charlotte HOT lane facilities.

These differences in revenue forecasts can be attributed to the relatively lower congestion levels and different assumed values of time and other factors that distinguish the Charlotte region from HOT lanes elsewhere, including both existing and proposed facilities. The results from the tolling model for Charlotte are consistent with findings from other cities when the differences in operating environment and policies are considered. Most importantly, this comparison should serve to increase the decision maker's confidence in the toll and revenue forecasts for *Fast Lanes* in the Charlotte region.

## **7.2 I-77 HOV-to-HOT Lanes Conversion Feasibility Study**

Revenue projections for the I-77 feasibility study were generated by the same tolling model used during the Charlotte Regional Fast Lanes Study. This special model again built upon forecasts from the Metrolina regional travel demand model.

### **7.2.1 Approach for Revenue Projections**

Similar to the methodology used at the regional level, toll revenues were dynamically optimized on a five-minute basis for I-77 segments for the weekday morning peak, midday, afternoon peak and evening periods. Annual revenue forecasts reflected estimates of average weekday volumes and weekend performance using weekday-to-weekend factors from other cities in the United States.

From the modeling results for the I-77 corridor, different revenue and toll estimates were generated by varying the following parameters:

- **Pricing objective.** Tolls were established in the I-77 feasibility study to 1) maximize toll revenues, and 2) minimize the aggregate dollar value of time costs in each corridor. For both scenarios, the managed lane was limited to carrying no more than 1,600 vehicles per hour per lane.
- **Carpool policy.** Demand and revenues were estimated for two policy scenarios – HOV 2+ free and HOV 3+ free.
- **Commercial Vehicles.** Demand and revenues were estimated for two policy scenarios related to commercial trucks where 1) delivery or two-axle trucks are prohibited from HOT lane use, and 2) the aforementioned commercial vehicles are permitted to pay a toll and enter the I-77 HOT lanes.
- **Year of operation.** Modeling was completed for two planning years, 2013 and 2030.
- **Build options.** Revenue and demand were forecast for scenarios involving construction of a general purpose lane or not in addition to the HOT lane. Build options also varied the overall length of the HOT lane facility.

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## 8.0 IMPLEMENTATION PARAMETERS

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### 8.1 Conversion of a HOV Facility to HOT Lanes

While a wide variety of issues affect how operations along an existing HOV facility can be modified to include tolling, the specific transition plan depends on the selected build option. At a minimum, adding tolling to existing HOV lanes will need to account for how the transition can take place without adversely affecting carpools and transit riders. Construction and lane closures may need to occur outside the peak commute hours.

If the transition plan must address any extensions of a current HOV project, then tolling of the current project should probably hinge on the date an extension is ready to be opened, so that the entire project opens at one time. Otherwise, tolled traffic will be required to exit the lane treatment prior to its ultimate terminus. The transition plan would need to account for a testing period for both transponders and tolling equipment, typically 90 days or more. If a HOT lanes project occurs in an area where there are no toll facilities or if it precedes a region's first toll road, a much higher level of advertising and awareness must be planned to establish transponder accounts and test back office functions.

### 8.2 Delivery Options

A wide range of project delivery options exist for HOV-to-HOT lanes conversion. Delivery options already practiced in North Carolina include:

- Traditional design-bid-build;
- Design-build;
- Third party public/private partnerships (PPP) in which design, delivery and maintenance are contracted out with a defined operating or franchise period;
- Variations of the above affecting financial options and payments.

Unless financial outcomes suggest substantial positive benefits relative to costs and revenue, a PPP option for a single corridor would likely not have enough merit to draw interest. It often occurs that the most competitive response for implementation involves a hybrid delivery approach in which the civil works are contracted either traditionally or by design-build, but the tolling systems integrator function is separately procured since this role may extend for several or many years into the future in a design-build-operate-maintain (DBOM) agreement. The rationale for DBOM relates to the different skill-sets associated with tolling system integration that already exist within NCDOT/NCTA. Further discussions with these groups would be needed in order to settle on a best approach for tolling system support.

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## 9.0 PUBLIC OUTREACH

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This chapter discusses public relations and outreach strategies for the introduction of, and possible changes to, HOV and HOT lanes based on national experience.

### 9.1 HOV Lanes

HOV lanes were originally conceived as a means to encourage carpooling and to increase person throughput in the transportation system. HOV lanes also ensure reliable transit trip times and protect the future mobility of a corridor. HOV restrictions manage traffic demand below “crush” capacity in order to improve travel time savings along a corridor when compared to adjacent general-purpose lanes. This travel time advantage, coupled with trip reliability, provide incentives for drivers to form carpools, vanpools or choose transit in order to bypass congestion.

Unfortunately, HOV lanes have not always provided the expected advantages. At various times, even within the same peak period, situations may arise in which the HOV facility operates with too many (or too few) vehicles during lane operation periods, leading to a number of potential problems. “Empty-lane syndrome” – the popular term for a condition in which HOV lanes are underutilized – can result when the lane is perceived to have too few vehicles (even if the HOV lane is moving more persons than the adjacent general purpose lanes). Peak-hour congestion in HOV lanes is another potential problem. Achieving the proper balance of managed lane use is a challenge for all HOV operators. There are other issues that stem from peak directional flows (i.e., too much demand in one direction and not enough in the other), and the efficient operation of HOV facilities becomes even more complicated. Agencies seeking to avoid or mitigate these lane performance problems will often consider and implement HOV lane policy changes as a solution.

Not all policy changes are motivated by operational difficulties. Other motivations for change could include maximizing system throughput, revenue generation in the case of HOT lanes, and legislative mandates. Opportunities for moving more vehicles through a particular corridor almost always exist, and changes to HOV policies can help to realize throughput gains. Implementation of tolling on HOV lanes may also provide revenue for lane maintenance, enforcement or expansion, transit improvements, or other purposes in the region. Revenue expectations on the part of the general public and elected officials may be in excess of actual revenue collected because the lane capacity available for congestion pricing may be limited and only provide benefits during the periods when congestion exists. Legislation, such as the allowing fuel-efficient hybrid-vehicles or motorcycles access to HOV lanes, can also drive policy changes.

Successful introduction and maintenance of a positive overall public attitude about HOV and HOT lanes depends largely on the policy and operations decisions that envision and support the attributes of the lane. The adage “You can’t sell a bad product” has never rung more true than when it is applied to HOV and HOT facilities, in part because many of the problems of the facility, such as unsafe design and poor enforcement, are glaringly apparent to both users and nonusers day after day after day.

Historically, “successful” HOV lanes – those lanes that open with a minimum of controversy and evolve into an integral part of how people expect to use their highways -- have been developed with a clear set of implementation parameters and operations expectations.

These parameters and expectations help to ensure that newly introduced HOV facilities should appease skeptical (and sometime hyper-critical) publics as well as serve the long-term interests of the community at large. Travelers, elected officials, environmental and business groups, and the media may all have different expectations for the HOV lane. Travelers may want a speedier and more reliable trip; environmental groups may associate the introduction of HOV or HOT lanes with a reduction in auto emissions; elected officials could look for HOV or HOT lanes to provide an easing of congestion in adjacent general purpose lanes; business interests may measure success by a decrease in parking demand at their worksite lots as more employees double up or take transit; and transit agencies may expect to gain additional customers because their buses can make faster and additional trips.

## 9.2 HOT Lanes

As HOT facilities have been introduced into the “managed lane” mix of different designs and operational strategies, expectations may take on a more “consumer-oriented” twist. If tolls are collected, how much will they be? What will the toll revenue be and how will it be spent? Will existing carpools lose their “free ride” status? If a traveler “paid” for a quick trip in a HOT lane, what is the reimbursement policy of that quick trip doesn’t materialize? Do only people with electronic transponders get to use the HOT lane? How much does a transponder cost and where can they be purchased, rented or gotten for free if required for carpools? What happens if the transponder breaks? How will violators be apprehended and fined? Developing and gaining internal acceptance for “fee-for-service” policies and their associated services may also be new if the sponsoring agency is, for instance, a department of transportation, as historically these types of agencies have been relatively egalitarian when structuring and delivering services.

















HOV lanes have been operating since the late 1960’s, and there are currently more than 150 individual HOV facilities in 20 states. Forty years of history developing, designing, opening and operating HOV lanes has provided a wealth of information on what to do (and not do) to help ensure success of future HOV facilities. Although the list – and experience - in the HOT lane arena is extremely limited due the small number of HOT facilities, many of the lessons learned from the HOV experience can be applied and expanded upon when thinking about introducing and operating HOT lanes.

**Figure 9-1** and **Figure 9-2** are checklists which provide valuable indicators to assess if a HOV or HOT facility stands a good chance of success. While few HOV projects have been terminated over the years, many and perhaps most have undergone significant design and operational changes to address pitfalls found after facility opening, in order to prevent being terminated. It’s wise to pay attention to both the successful characteristics of HOV and HOT facilities and the issues or challenges that can potentially doom a project. The checklists have been developed and updated over the past 20 years as projects (and the communities where they have been introduced) have evolved and changed. It provides a template to help determine where special attention needs to be paid and to ensure that the HOV and/or HOT product is the best, and most acceptable, that can be provided to the community. These checklists also help to identify those areas that may be “weak”, such as less than optimal transit service or poor media relations, so work can begin to improve those elements long before a HOV or HOT facility is introduced.

**Figure 9-1: Checklist for Successful HOV or HOT Facility Implementation**

	<b>Checklist to Success</b> <i>Characteristics for successful freeway HOV Facility implementation</i>
	Clear set of objectives and measures of success
	Introduce HOV lane as an additional lane
	Existing congestion in corridor (able to save 1/minute/mile & 5 to 8 minutes total in the HOV lane)
	Projections for continued increase in demand
	Enforcement commitment/collaborative working relationships with enforcement agencies/courts along the corridor
	Ability to provide a lane that will be safely operated and enforced
	Ability to secure project implementation support from agencies and public
	HOV policies supported by elected officials
	Policies and programs supporting transit use
	Rideshare program in corridor
	Successful HOV facilities already in operation in same corridor or adjacent corridors
	High existing volume of 2+ HOV's (700 or more vehicles per hour)
	Traffic system management system program already in place along the corridor
	High level of convenient transit service along the corridor (local/express/Park & Ride routes)
	Commute trip reduction legislation
	Existing communication network with employers along the corridor
	Collaborative working relationships with environmental agencies/groups along the corridor
	Collaborative working relationships with neighborhood/community groups along the corridor
	Collaborative working relationships with local jurisdictions/transit agencies/DOT's along the corridor
	Commitment to evaluation to accurately show benefits/disbenefits
	Origin-destination pattern that can benefit from the HOV lane
	Able to construct HOV facility with minimal disruption to existing freeway flow
	Legend  = <b>Essential Characteristic</b>  = <b>Desirable Characteristic</b>

**Figure 9-2: Potential Pitfalls to Successful HOV or HOT Facility Implementation**

<b>Potential Pitfalls to Successful HOV Facility Implementation</b>	
	Converting existing general purpose lane to HOV lane which results in negative impact (increased accidents, increased travel time, etc.) in adjacent general purpose lanes
	High accident rate along the corridor that will not be improved by HOV lane
	Little support from enforcement authorities (State Police/Patrol, municipal judges/magistrates)
	Low existing volume of HOV's
	Poor working relationships with local media
	Poor working relationships with neighborhood/community groups along the corridor
	Poor working relationships with elected officials (especially critical during election years)
	Changing lane designation from general purpose to HOV during lane construction (example: begin construction as general purpose, change designation during construction phase to HOV)
	Low level of transit service
	Lack of transit funding
	No/low level of support facilities
	No incident management program in place
	No/inadequate ridematching services
	Poor pavement maintenance of adjacent general purpose lanes that would not be helped by HOV lane construction
<b>Legend</b>  = <b>Potential Fatal Flaw</b>  = <b>Possible Problem</b>	

### 9.2.1 HOT Lanes Concept Education

Introducing a HOT lanes project can present a unique set of public affairs challenges. Typically HOT lanes are introduced through a conversion of an existing HOV lane. If the goal of the new HOT lane is to maintain HOV market share and “sell” remaining space to single occupant vehicles, special care needs to be taken to ensure that new HOT policies do not negatively impact the existing HOV market share. For example, it is possible that HOT operations policies – such as requiring transponders for all HOT lane users regardless of occupancy to improve enforceability – may dilute the HOV market share, as carpools that have the prerequisite number of people but lack transponders would be barred from no-charge HOT lane usage. Additionally, existing carpools may disband, as they can now “buy”, rather than “behave” their way into a speedy and reliable trip in previous HOV/now HOT lane. The project team needs to carefully weigh the effect each operational policy will have on HOV market share, and proceed with strategies that ensure maximum HOV retention. However, if revenue generation rather than congestion management through maximizing HOV market share is the goal, a different set of marketing and communication actions needs to be undertaken.

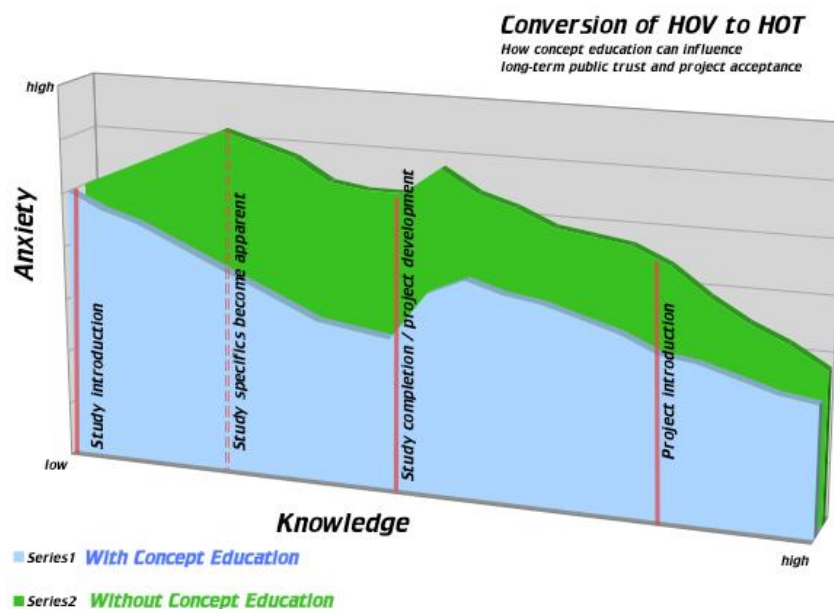


Although each HOT facility has unique goals and characteristics, how the public will react to their consideration remains relatively constant. When HOT projects are first being evaluated and considered, the general public wants to know 1) what they are, 2) why they are better than the status quo, and 3) how will they affect me and my travel. Local public affairs folks often have a difficult time responding immediately and with candor to questions posed by a variety of publics (local and regional elected officials, corporate and neighborhood groups, environmental concerns, media) because the concept is still relatively unfamiliar to the spokesperson. Because studies weighing the pros and cons of projects are underway, spokespersons' responses can appear vague ("we are just beginning the study") or evasive ("I can't answer that question at this time as I don't have enough information"). These types of responses do little to reassure a skeptical public, and in fact, can often increase anxiety about the "what ifs" of potential project considerations. In the best case, too little or too vague information only results in inaccurate perceptions that must be corrected later. Worse case scenarios can include inflammatory reporting, anxious calls to elected officials, and project (study) changes in scope and/or schedule.

When details of a project do come out, public anxiety has already been aggravated so details are looked upon with suspicion. To ready the public for acceptance of future HOT lanes concepts, special care needs to be taken to get the project started "on the right foot" by preparing publics to at least be willing to initially consider pricing as a possible congestion management or revenue generation tool. For this reason, it is wise to consider implementation of a HOT facility Concept Education Plan prior to, or at a minimum, when a HOT lanes study is in its very early stages. Without a lead-up HOT lanes concept education effort, a study, and perhaps the associated project, may find itself continually trying to win the public's trust and confidence up to and even after project opening.

**Figure 9-3** illustrates how concept education can influence public trust and acceptance of a HOV-to-HOT lanes conversion project.

**Figure 9-3: Benefits of HOT Lanes Concept Education**



HOT lanes concept education is macro in scope. It provides the “big picture” information and the foundation for future individual studies and subsequent projects. It is educational (as opposed to “sales”) in its approach and points out the advantages and disadvantages associated with pricing. The primary purpose of HOT lanes concept education is to reduce anxiety (fueled by inaccurate information) by increasing knowledge.

HOT lanes concept education prepares publics – travelers, businesses, elected officials, environmental groups, community groups, the media – to rationally and calmly consider and evaluate individual HOT lanes projects based on merit rather than bias. In a political campaign, an advance team arrives at events before the candidate to make sure everything is in order. HOT facility introduction also requires an advance team, providing publics with HOT lanes information of a general nature. This information should include:

- What is congestion pricing
- Why congestion pricing is relevant
- How congestion pricing can benefit motorists
- The forms that congestion pricing can take

Information about congestion pricing projects in other parts of the United States and around the world, testimonials from users of existing HOT facilities, elected officials and environmental groups associated with congestion pricing projects, and references to United States policies supporting congestion pricing help to prepare the public for the introduction of a specific HOT lanes study and perhaps subsequent projects.

Resources for developing HOT lanes concept education elements are constantly being expanded and updated. The following websites and documents are currently available when developing a HOT facility concept education strategy:

- <http://ops.fhwa.dot.gov/publications/congestionpricing/congestionpricing.pdf>
- <http://www.edf.org/page.cfm?tagID=6241>
- [http://www.calccit.org/itsdecision/serv\\_and\\_tech/Congestion\\_pricing/congestion\\_pricing\\_summary.html](http://www.calccit.org/itsdecision/serv_and_tech/Congestion_pricing/congestion_pricing_summary.html)
- <http://www.tfhr.gov/pubrds/04nov/08.htm>
- "Moving Forward with Managed Lanes," Resource CD Toolbox, Publication Number: FHWA-HOP-07-030 - This toolbox includes a 10-minute video on an overview of managed lanes concept including highlights of real world applications. Contact [Jessie.Yung@dot.gov](mailto:Jessie.Yung@dot.gov) for a copy.
- [http://www.hovworld.com/publications\\_assets/MgdLanes.TTI.pdf](http://www.hovworld.com/publications_assets/MgdLanes.TTI.pdf)
- [http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS\\_TE/13668.html](http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13668.html)
- <http://isddc.dot.gov/OLPFiles/OST/012988.pdf>